ENCYCLOPEDIA OF GERONTOLOGY

Second Edition

AGE, AGING, *and the* AGED

Encyclopedia of GERONTOLOGY

SECOND EDITION

EDITOR-IN-CHIEF AND EDITORIAL ADVISORY BOARD

ENCYCLOPEDIA OF
GERONTOLOGY

SECOND EDITION

EDITED BY

JAMES E. BIRREN

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About the Editor-in-Chief

James E. Birren's many awards include the Award of the President of the American Society on Aging (1996), the Brookdale Foundation Award for Gerontological Research, the Sandoz prize for Gerontological Research, and the Award for Outstanding Contribution to Gerontology by the Canadian Association of Gerontology. Dr. Birren is currently Associate Director of the Center on Aging at the University of California, Los Angeles, and serves as an adjunct professor in medicine, psychiatry, and biobehavioral sciences. He is also Professor Emeritus of Gerontology and Psychology at the University of Southern California. Dr. Birren's previous positions include serving as the chief of the section on aging of the National Institute of Mental Health, the founding executive director and dean of the Ethel Percy Andrus Gerontology Center of USC, the founding director of the Anna and Harry Borun Center for Gerontological Research at UCLA, and as the president of the Gerontological Society of America, the Western Gerontological Society, and the Division on Adult Development and Aging of the American Psychological Association. Author of more than 250 scholarly publications, Dr. Birren's research interests include how speed of behavior changes with age, the causes and consequences of slowed information processing in the older nervous system, the effect of age on decision-making processes, and the role of expertise in skilled occupations. He has served as a delegate to several White House Conferences on Aging and continues to develop national priorities for research and education related to issues of aging. Currently he is teaching about autobiography and has received a Mind Alert award from the American Society on Aging to conduct study groups throughout America.

About the Editorial Advisory Board

Gloria M. Gutman developed and directed the Gerontology Department and Gerontology Research Centre at Simon Fraser University in Vancouver, Canada, from 1982 to 2005. Currently she is a professor in the department and the Director of the Dr. Tong Louie Living Laboratory. She is the author/editor of 20 books and monographs and over 150 scholarly articles, reports, and chapters on seniors' housing, long-term care, epidemiology of dementia, health promotion, and aging and technology. She was the founding president of the Gerontology Association of British Columbia, served two terms as the President of the Canadian Association on Gerontology, was the President of the International Association of Gerontology and Geriatrics from 2001 to 2005, and as an immediate past president, will serve on the IAGG Executive until 2009. She is a fellow of the Gerontological Society of America, a director of the International Institute on Ageing United Nations-Malta, a member of the World Health Organization's Expert Advisory Panel on Health and Ageing and serves on the editorial boards of six journals in the area of gerontology and geriatrics. In 2001, Dr. Gutman was named "one of 130 who make a difference" by the *Vancouver Sun* newspaper and was the recipient of the Canadian Association on Gerontology's Distinguished Member Award. In 2005, she was presented with the prestigious Rosalie Wolf award by the International Network for Prevention of Elder Abuse.

Victor W. Marshall is Professor of Sociology at The University of North Carolina at Chapel Hill, and director of the UNC Institute on Aging. Prior to that, he served as director of the Institute for Human Development, Life Course and Aging at The University of Toronto. From 1990 to 1995 he was the director of the Canadian Aging Research Network, a federally funded nationwide network of Centers of Excellence. Professor Marshall is a fellow of the Gerontological Society of America and a founding member and former Vice President of the Canadian Association on Gerontology. He currently serves on the editorial boards of *Ageing and Society*, *Journal of Aging and Health*, and *Social Forces*. Marshall's published research has covered such diverse aspects of aging as the family, long-term care, migration, and death and dying, but more recently he has focused on the aging workforce, the changing retirement transition, healthy aging, aging and public policy, and social theory in aging and the life course.

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Contributions award from the American Psychological Association. He is the author/editor of 51 books, including the textbook *Adult Development and Aging* (5th edition, with S. L. Willis), and the *Handbook of the Psychology of Aging* (6th edition, with J. E. Birren). He has directed the Seattle Longitudinal Study of Cognitive Aging since 1956 and is the author of more than 275 journal articles and chapters on the psychology of aging. His current research interests are the life course of adult intelligence, its antecedents and modifiability, the early detection of risk for dementia, as well as methodological issues in the developmental sciences.

Edward J. Masoro was the recipient of the 1989 Allied-Signal Achievement Award in Aging Research. In 1990, he received the Geriatric Leadership Academic Award from the National Institute on Aging and the Robert W. Kleemeier Award from the Gerontological Society of America. In 1991, he received a medal of honor from the University of Pisa for Achievements in Gerontology, and in 1993, Dr. Masoro received the Distinguished Service Award from the Association of Chairmen of Departments of Physiology. In addition, he received the 1995 Irving Wright Award of Distinction of the American Federation for Aging Research and the 1995 Glenn Foundation Award. He served as President of the Gerontological Society of America from 1994 to 1995, as Chairman of the Aging Review Committee of the National Institute on Aging (NIA), and as Chairman of the Board of Scientific Counselors of the NIA. Dr. Masoro has held faculty positions at Queen's University (Canada), Tufts University School of Medicine, University of Washington, and Medical College of Pennsylvania. From 1973 through May of 1991, he served as the Chairman of the Department of Physiology at the University of Texas Health Science Center at San Antonio. He currently continues his duties as Professor Emeritus in the Department of Physiology and is the director of the newly created Aging Research and Education Center. He currently is a Professor Emeritus in that department and a member of the Barshop Institute for Longevity and Aging Studies of that institution. He continues to serve on the editorial boards of five journals: *Aging Cell*; *Experimental Gerontology*; *Journal of Gerontology*: *Biological Sciences*; *Growth, Development and Aging* and is also editing books (e.g., *Handbook of the Biology of Aging*, 6th edition) and writing books (e.g., *Caloric Restriction: A Key to Understanding and Modulating Aging*).

Thomas R. Cole is the Beth and Toby Grossman Professor and director of the McGovern Center for Health, Humanities, and the Human Spirit at the University of Texas Health Science Center in Houston. He is also the Chavanne Visiting Professor in the Department of Religious Studies at Rice University. Cole graduated from Yale University (BA in Philosophy, 1971), Wesleyan University (MA in History, 1975) and the University of Rochester (Ph.D. in History, 1981). Dr. Cole has published many articles and several books on the history of aging and humanistic gerontology. His book *The Journey of Life: A Cultural History of Aging in America* (Cambridge University Press, 1992) was nominated for a Pulitzer Prize. He is a senior editor of *What Does It Mean to Grow Old?* (Duke, 1986), the *Handbook of Humanities and Aging* (Springer, 1992, 2nd edition, 1999) and *Voices and Visions: Toward a Critical Gerontology* (Springer, 1993). The *New Yorker* noted his co-edited *Oxford Book of Aging* as one of the most memorable books of 1995. His most recent co-edited book is *Practicing the Medical Humanities* (2003). Cole's interest in the life stories of older people has taken him into biography and film making. In 1984, he encountered Eldrewey Stearns, a hospitalized psychiatric patient who claimed he was the "original Texas integration leader." Their collaboration resulted in a book *No Color is My Kind: the Life of Eldrewey Stearns and the Desegregation of Houston* (1997) and an accompanying film, *The Strange Demise of Jim Crow*, broadcast nationally on over 60 PBS stations and internationally by the State Department. The documentary received numerous awards and was nominated for a regional Emmy and a National Humanities Medal. Cole's film *Still Life: The Humanity of Anatomy* was an official selection at the Doubletake Documentary Film Festival in April 2002. This work explores the special yet unstated relationship between medical students in the anatomy lab and the people who donate their bodies for dissection. In 2001, Cole's writing workshop program for elders was featured in the PBS documentary *Life Stories*. Both films probe relationships between present and past, the living and the dead as crucibles of moral and spiritual development. Most recently, Cole co-produced *Living with Stroke*, a film about the invisible world of stroke survivors, which will be broadcast and distributed in 2007. Cole's work has been featured in the *New York Times*, National Public Radio, Voice of America, PBS, and at the United Nations. He serves as an advisor to the United Nations NGO Committee on Ageing, the Union for Reform, Judaism's Department of Family Concerns, and various editorial and foundation boards. In 2004–2005, he served as a consultant to the project on aging conducted by the President's Council on Bioethics, which was recently released in print as *Taking Care*.

David H. Solomon, MD, has been one of the leaders in the renaissance of geriatrics, which began in the late 1970s. In the American Geriatrics Society, he has been a member of the Board of Directors of AGS, editor of the *Journal of the American Geriatrics Society,* and a recipient of the Milo Leavitt Award, the Edward Henderson Award and the Award for Distinguished Service from AGS, as well as the Freeman Award of the Gerontological Society of America. A new award of the AGS has been named for him, the David H. Solomon Distinguished Public Service Award. For over 25 years, his focus has ranged from endocrinology and academic administration (Chairman of the Department of Medicine at Harbor-UCLA Medical Center and Executive Chairman of Medicine at UCLA) to geriatric medicine, where he has been the Associate Director of the Multi-campus Programs in Geriatric Medicine and Gerontology, a Founding Director of the UCLA Center on Aging and an active teacher, researcher and clinician in the field of geriatrics. He has played a key role nationally in the introduction of geriatrics education and training into the residency programs of surgical and related medical specialties and in research in the ACOVE project at the RAND Corporation on the measurement and attempted improvement of the quality of health care received by vulnerable older people.

FOREWORD

Efforts to assemble a comprehensive reference of universal knowledge date back to Aristotle, and some consider the work *Natural History* of Pliny the Elder to be the first encyclopedia. By the nineteenth century, encyclopedias had become more specialized, in line with expanding knowledge that required many sources. The *Encyclopedia of Gerontology,* second edition, is illustrative of the character of gerontology itself, universal by its capacious nature, while at the same time specialized. That is one reason, among many, that makes the field so extraordinary and inviting. The growth of aging populations and the advance of longevity, after all, reflect one of the great universal historic demographic shifts of all time. And with this revolution in longevity have come numerous challenges – social, economic, political, ethical, and personal – requiring a range of special adjustments. This fine encyclopedia reflects both the challenges and the adjustments.

Conventional knowledge notes that as societies increase in wealth, they are in a better position to provide social, health, and other benefits for their citizens. But based upon recently acquired knowledge, the reverse is also true, that health and longevity promote wealth. Svanborg, Manton, and others have found that as a result of social, medical, and public health advances, people not only are living longer but also are more likely to enjoy more disability-free years. These two facts strengthen the prospectus for increasing years of productive engagement. This demographic shift constitutes a great human achievement, compelling, in turn, the transformation of our culture and the personal experience of growing older that is at hand. It will lead to a body of new concepts and data concerning old age – and to an expanding encyclopedia.

Robert N. Butler, M.D.
President and CEO
International Longevity Center
Professor of Geriatrics and Adult Development
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PREFACE

This second edition of the *Encyclopedia of Gerontology* reflects the dramatic growth of research and scholarship about aging. The study of aging has emerged as not only an area of scientific and scholarly effort but also an area of practical concern, as people are living longer and are more active, and the societies in which they live are changing. Aging is a complex process of change, involving influences of a biological, behavioral, social, and environmental nature. As the content of this second edition of the *Encyclopedia of Gerontology* reveals, aging is one of the most complex topics facing science in the twenty-first century.

Parallel with the expansion of research on aging, there has been an increased interest in issues relating to older persons in developed and developing countries. Evidence from new studies of aging is replacing long-standing stereotypes about older persons and the causes of change. How change is brought about in individuals over the life span results from many influences that range from genetics to physiology, sociology, psychology, and anthropology. Human life is influenced by physical, social, and economic environments as well as the traditions of families and religion. The articles in this encyclopedia have been selected to reflect both the depth and the breadth of influences on the living organism.

The second edition of the *Encyclopedia of Gerontology* includes both new topics and advances in areas included from the previous edition. In some cases, the updated articles are written by the same author, and in other cases, they are written by new authors with fresh perspectives. An international editorial advisory group was consulted in developing both the list of contents and the contributors for each article. The efforts of the authors, editors, reviewers, and publishing staff have been very important in the completion of this volume and are greatly appreciated.

The encyclopedia provides updates and summaries about what is known about the many processes of aging. As before, the topics are arranged alphabetically. Readers are encouraged to use the comprehensive index at the end of the encyclopedia, since a topic of interest may be dealt with under different terms by different authors.

James E Birren

How to Use the Encyclopedia

The *Encyclopedia of Gerontology*, second edition is intended for use by both students and research professionals. Articles have been chosen to reflect major disciplines in the study of gerontology and adult development and aging, common topics of research by professionals in this realm, and areas of public interest and concern. Coverage includes five major areas: the biology of aging, the psychology of aging, aging and the social sciences, health sciences, and the humanities and aging. Each article serves as a comprehensive overview of a given area, providing both breadth of coverage for students and depth of coverage for research professionals. We have designed the encyclopedia with the following features for maximum accessibility for all readers.

Articles in the encyclopedia are arranged alphabetically by subject. Complete tables of contents appear in both volumes. Here, one will find broad discipline-related titles such as "Demography" and "Pharmacology," research topics such as "Dementia" and "Creativity," and areas of public interest and concern such as "Abuse and Neglect of Elders" and "Ethics and Euthanasia."

The Index is located in Volume 2. Because the reader's topics of interest may be listed under a broader article title, we encourage use of the Index for access to a subject area, rather than use of the Table of Contents alone. For instance, Alzheimer's Disease is covered under the title "Dementia: Alzheimer's", "Dementia," and olfaction is covered in the article "Smell and Taste." Because a topic of study in gerontology is often applicable to more than one article, the Index provides a complete listing of where a subject is covered and in what context.

Each article contains a glossary, cross references, and a list of recent and seminal primary and secondary sources for further reading on the topic. The glossary contains terms that may be unfamiliar to the reader, with each term defined *in the context of its use in that article*. Thus, a term may appear in the glossary for another article defined in a slightly different manner or with a subtle nuance specific to that article. For clarity, we have allowed these differences in definition to remain so that the terms are defined relative to the context of each article.

Each article has been cross-referenced to other articles in the encyclopedia. Cross-references are found within the body of the article and at the close of the article before the further reading suggestions. We encourage readers to use the cross-references to locate other encyclopedia articles that will provide more detailed information about a subject.

The further reading section lists sources to aid the reader in locating more detailed or technical information. Review articles and research articles that are considered of primary importance to the understanding of a given subject area are also listed. The further reading section is not intended to provide a full reference listing of all material covered in the context of a given article, but is provided as a guide to additional sources of information on the subject.

A

Abuse and Neglect of Elders

L McDonald, University of Toronto, Toronto, ONT, Canada

Glossary

Elder Abuse – Intentional actions that cause harm or create a serious risk of harm, whether or not intended, to an older adult by a formal or informal caregiver who has a trust relationship with the elder, or failure by a caregiver to satisfy an older person's fundamental needs or to protect the elder from harm.

Formal Caregivers – Professionals and semi-professionals, such as social workers, physicians, lawyers, homecare providers, and nurses, who care for older persons in a wide variety of settings.

Informal Caregivers – Family members or close family associates who care for the older person, either in the older person's own home or in the caregiver's home.

Neglect – Intentional or unintentional harmful behavior on the part of an informal or formal caregiver in whom the older person has placed his or her trust. Unintentional neglect is the failure of the caregiver to fulfill a caretaking responsibility, but without the intention to harm the older person; intentional neglect occurs when the caregiver consciously and purposely fails to meet the needs of the older person, resulting in psychological, physical, or material injury to the older person.

Self-neglect – An act of omission on the part of the older person, such as the failure to take care of personal needs, that may result in psychological, physical, or material injury. The problem can often be attributed to the older person's diminished physical or mental capabilities to care for him- or herself. There is some question as to whether self-neglect should be included in a consideration of elder neglect and abuse, since no abusive caregivers are involved.

Introduction

Elder abuse, also called mistreatment or maltreatment, is harmful behavior directed toward older persons by informal or formal caregivers who the older person loves or trusts, or on whom they depend for assistance. The destructive behavior can cause physical, psychological, or material injury to the older person, resulting in unnecessary distress, suffering, and sometimes death. Historically, there has been no generally accepted definition of elder abuse, but there is a growing international consensus about the types of actions to be included in the definition. There are usually five agreed-upon categories of abuse, with some disagreement about whether self-neglect and abandonment are forms of elder abuse. Physical abuse includes any act that involves the intentional infliction of physical discomfort, pain, or injury. Examples of physical abuse include such behaviors as restraining, slapping, kicking, cutting, or burning. Medical maltreatment is sometimes considered an example of physical abuse. Sexual abuse or assault covers any kind of nonconsensual sexual contact with an older person, such as unwanted touching, all types of sexual battery, such as rape, or coerced nudity. Psychological abuse, sometimes referred to as verbal or emotional abuse, involves the intentional infliction of mental anguish or the provocation of fear of violence or isolation in the older person. Psychological abuse can take various forms, such as name-calling, humiliation, intimidation, or threats of placement in a nursing home. Material abuse, often referred to as financial abuse, involves the intentional, illegal, or improper exploitation of the older person's material property or financial resources by the abuser. Material abuse can include fraud, theft, or use of money or property without the older person's consent. Neglect generally refers to the intended or unintended failure of a formal or informal

caregiver to fulfill any part of a caregiving obligation. Examples include failure to provide an older person with the necessities of life such as food, water, clothing, shelter, medicine, or comfort. Acts such as theft, physical assault, rape, or burglary by a person outside of a trusting relationship with the older person usually would not be classified as elder abuse, but rather as crimes. Crimes against the elderly include some, but not all, forms of elder abuse.

These categories of abuse have been strongly influenced by research in Canada, the United Kingdom, Europe, and the United States. Studies conducted in other countries such as China, India, and South Africa have used different definitions that reflect the values within their societies. In China, where harmony and respect are core societal values, neglecting the care of an older person is considered elder abuse. In one of the first attempts to classify abuse in a developing country, focus groups held in South Africa added to western definitions such categories as accusations of witchcraft, loss of respect for elders, and abuse by systems such as health clinics and pension offices.

The abuse of older people by family members did not come to light until after child and wife abuse had entered the public domain in the mid-1960s. Elder abuse was first described as late as 1975 in British scientific journals as 'granny battering' but rapidly came to be regarded a significant social problem in developed countries in the 1980s. With the realization of the dramatic increases in the aging populations in developing countries in the 1990s, elder abuse became a global issue. This article reviews the extent of elder abuse in domestic and institutional settings, the risk factors for mistreatment, the theoretical frameworks used to explain abuse, and global responses to the problem.

The Extent and Social Context of Elder Abuse

Elder Abuse in Domestic Settings

Although many studies have documented the existence and nature of elder abuse and neglect, only a few international studies have collected data on the prevalence (total number of occurrences in a given time period) and the incidence (number of new occurrences within a specific time) of the problem among the non-institutionalized elderly. Reliable data have been difficult to obtain because definitions of elder abuse and neglect vary, the problem is recurrent, methodologies and time frames for the occurrence of abuse differ, and samples sometimes do not accurately represent older people. In light of these difficulties, rates from international sources range from 2 to 10% and should be interpreted with some caution.

In the United States, one of the first prevalence studies was carried out in the greater Boston area in 1985–86 based on a representative sample of 2020 persons, all 65 years of age or older. The study found that 3.2% of the elders had experienced some type of abuse. About 2% of the sample were physically abused, 1.1% were chronically verbally abused, and about 0.4% were neglected. Material abuse was not considered in this investigation, resulting in a generally lower prevalence rate than in other studies. In contrast, telephone surveys in Sweden and Denmark indicated that 8% of elders reported abuse, but theft was included as a type of elder abuse. A study done in a small town in Finland found that 5.7% of a representative sample had been abused since the time they retired. A study in Canada used a representative sample to conduct a national telephone survey in 1989 of 2008 randomly selected older persons. This investigation found that about 4% of the sample reported some type of abuse. Approximately 2.5% of the sample experienced material abuse, 1.4% experienced chronic verbal aggression, and 0.5% suffered physical abuse. About 0.4% reported neglect. A more recent study, reported in 1998, was a study in Amsterdam of a representative sample of persons 69 years of age and older. It found that the 1-year prevalence of elder abuse was 5.6%.

The prevalence rates appear to be relatively low, but they may also be misleading. Although these studies represent the best prevalence studies currently available, they all suffer from flaws in design and implementation; they are subject to cultural and contextual differences; and, more than likely, they provide low estimates because the cognitively or hearing impaired have been excluded from at least two of the investigations. There is little doubt that better prevalence data using large-scale random samples on either locally or nationally representative samples are required.

Incidence rates for elder abuse are still virtually unknown in most countries. However, attempts at estimates have been made by the National Center on Elder Abuse at the American Public Human Services Association. In the National Elder Abuse Incidence Study, data on domestic elder abuse, neglect, and self-neglect were gathered through a nationally representative sample of 20 counties in 15 states. Using reports from local Adult Protective Agencies and from 'sentinels' who are specially trained individuals at a variety of agencies, the study uncovered approximately 450 000 adults age 60 and over who were newly abused or neglected in domestic settings in

1996. The study also estimated that for every reported incident of elder abuse and neglect, approximately four incidents go unreported. Female elders were abused at higher rates than males, and in almost 90% of the cases, the perpetrator was a family member; two-thirds of the perpetrators were adult children or spouses. The incidence study has been questioned on methodological grounds to the extent that many older vulnerable people do not have contact outside of their homes and thus are often reluctant to take action against their abuser, so are not identified as mistreated.

Elder Abuse in the Institution

Institutional abuse is the mistreatment of older persons living in facilities such as nursing homes, hospitals, or long-term care institutions; it is perpetrated by the formal caregiving staff, and sometimes by other patients or visitors. There is, however, some indication that an abusive relationship at home may not necessarily end once an older person has entered institutional care. Elder abuse and neglect by formal caregivers fall into the same categories as that committed by informal caregivers, but the victims are likely to be more vulnerable to abuse because they require the protective environment of the facility. Some researchers have added violations of basic rights to the list of abuses that can occur in institutions. Such violations include denying elderly people the right to make personal decisions or the right to privacy. Another form of abuse that has been considered is systemic abuse, which refers to abuses resulting from unquestioning regimentation, such as routine use of incontinence briefs instead of helping the person to the bathroom.

There are no reliable data on the prevalence of maltreatment or neglect in hospitals, nursing homes, day care, or residential long-term care facilities. There is enough anecdotal evidence (case studies, governmental reports, ethnographic studies, personal histories) in every country where these institutions exist, however, to suggest that abusive behavior is a widespread, regular aspect of institutional life. There have been reports of material abuse, including the theft of patient's funds and fraudulent therapy and pharmaceutical charges; physical abuse, including rough handling, hitting and slapping, and inappropriate medical treatment such as chemical and physical restraint; and psychological abuse, including social isolation, yelling in anger, and threats. Neglect often reflects deficiencies in the provision of nursing care such as inadequate nutrition and hydration and poor oral and physical hygiene.

The first prevalence study of abuse in nursing homes was carried out in the United States. In a random survey of 577 nurses and nursing home aides in 1989, staff were asked to report on abuse perpetrated by others and to report on their own abusive actions. Only physical and psychological abuse were considered. The researchers found that, overall, 36% of the sample had seen at least one incident of physical abuse in the preceding year. The most frequent type of physical abuse observed by the staff was the excessive restraint of patients. A total of 81% of the surveyed staff had witnessed at least one psychologically abusive incident in the preceding year. Ten percent of the nurses reported that they themselves had committed one or more physically abusive acts, the most common being the excessive use of restraints (6%). Forty percent of the nurses admitted to psychological abuse, the most common form being yelling at a patient (33%). A more recent training project conducted a non-random survey of 77 certified nurses aids (CNAs) about whether they had witnessed abuse. Their reports supported the first American study. Fifty-eight percent of the CNAs said they had seen a staff member yell at a resident; 36% had seen residents insulted, 11% had witnessed threats to hit or throw something at a resident, and 21% had seen a resident grabbed, pushed, shoved, or pinched in anger.

In a random telephone survey of 804 nurses and nurses aids in Ontario, Canada, 20% reported having witnessed abuse of patients in nursing homes, 31% witnessed rough handling of patients, and 28% witnessed yelling and swearing at patients. A study of workers in Sweden (which included a few home-care workers) revealed that 11% of workers knew of at least one incident of abuse in the last year.

As in the analysis of domestic abuse, several North American scholars identified a number of factors that they believe contribute to the abuse of elderly residents by staff in nursing homes. These factors include the lack of comprehensive and consistent policies with respect to the infirm elderly, the fact that the long-term care system is characterized by built-in financial incentives that contribute to poor-quality care, the poor enforcement of nursing home standards, the lack of highly qualified and well-trained staff, the powerlessness and vulnerability of the elderly residents, especially those with some type of dementia or memory loss, and the tendency of staff to avenge patient aggression.

In a partial test of a model developed to explain abuse in institutions, the researchers found evidence that the maltreatment of nursing home patients appeared to be a response to highly stressful working conditions rather than a consequence of the characteristics of the nursing home such as the size or ownership status of the institution. Staff who were

younger, who were burned-out, and who experienced aggression from patients were more at risk of becoming abusive toward their elderly patients.

Risk Factors for Elder Mistreatment

Accurate research on risk factors for abuse is critical for the development of effective screening tools and intervention protocols, for reducing or eliminating contributing factors to deter mistreatment, and for the development of policy for those populations at heightened risk of mistreatment. As is the case with incidence and prevalence rates, the risk factor literature on elder mistreatment is both limited and inconsistent.

The first wave of research on elder abuse, beginning in the late 1970s, concluded that the typical victim at risk for abuse was a female over 75 years of age, with debilitating physical and psychological impairments and dependent upon a family caregiver, usually a daughter. Research at the end of the 1980s, based on sounder methodologies, cast some doubt on these observations and indicated that the situation was far more complex than was originally presumed. The focus shifted from the classification of the at-risk victim to the classification of the perpetrator, and to profiles of different combinations of victims, perpetrators, and types of abuse. In the early twenty-first century, mounting research evidence emphasizes the interactive aspects of elder abuse and supports distinctions between patient-directed, patient-generated, and mutual abuse.

Two decades of careful research can be distilled into five major observations. First, several studies, primarily done in North America, indicated that a shared living situation is a major risk factor for abuse, and, conversely, older adults living alone have the lowest risk of mistreatment. Shared housing and, in some countries, over-crowded quarters can increase interpersonal contacts and the possibility for mistreatment. There is the likelihood that there is a differential role of living arrangement according to type of mistreatment, but this requires further investigation. Second, family violence research has consistently discovered some degree of social isolation in almost all violent situations. Similarly, several empirical studies in North America and Scandinavia have found that abused elders were significantly more likely to have fewer contacts with friends and family members than were non-abused elders. This finding was interpreted to mean that there is less likelihood for violence when an older person has strong and active family and social ties. The presence of involved family and friends not only might deter violent behavior but also could provide additional support that would modify the caregiver's sense of burden and stress. Third, a number of studies have found higher rates of physical abuse in older adults with dementia when compared with the abuse rates in the general older population. Several findings, however, suggested that dementia itself is not the risk factor but rather the behavior that results from the caregiver violence. Fourth, the personality traits of the perpetrator, also referred to as the intra-individual characteristics of the abuser, are based on observations from a number of studies that discovered that an inordinately high proportion of abusers had histories of psychiatric illnesses and problems with drugs and alcohol. Depression appeared to be a common characteristic, and alcohol the most frequently used drug. Last, several research studies showed that abusers are more dependent on their older victims for financial support and for housing than are comparable groups of non-abusers.

There is only mixed or limited support for the views that older women are more likely to be abused, that adult children are the primary abusers, and that victims show higher levels of aggression. There is very limited support for the idea that race is a risk factor for elder abuse. Research has generally failed to find support for the view that frailty or dependency of the older adult is a risk factor for abuse, and, most importantly, there has been no support for the view that greater caregiver stress leads to mistreatment. The only two studies that examined the transmission of intergenerational violence as a risk factor for elder abuse found no evidence to support this hypothesis, contrary to research findings on other forms of family violence.

Theoretical Explanations

Much of the literature on elder abuse does not make the important distinction between theoretical explanations and the individual factors related to abuse. A theory provides a general, systematic explanation for observed facts; in the elder abuse literature, particular factors, such as stress or dependency, are often treated as complete theoretical explanations even though they are only factors and could be incorporated in any of a number of theories. The specific relationships between the various factors and elder abuse form propositions upon which theories are built. Over the course of the brief history of elder abuse, different accounts of the relationships among the factors have led to at least four distinct theoretical perspectives. Their variations are of particular import, since each theory determines what actions should be taken to ameliorate the abuse and neglect.

The Situational Model

Probably the first and most widely accepted perspective is the situational model, which has its roots in the mainstream perspectives on child abuse and family violence. The basic premise of the situational model is that stressful situations cause the caregiver to abuse the older person, who is usually viewed as the source of the stress. This approach suggests that mistreatment is an irrational response to stressful situations. The situational variables that this theory links to abuse include factors related to the caregiver and the elder as well as social and economic conditions. Interventions grounded in this perspective attend to reducing the stress of the caregiver. One major flaw of this perspective is that it fails to account for the fact that many caregivers, who experience the same stresses as abusers, do not mistreat their elderly. The perspective has also been criticized for being dangerously close to blaming the victim, since it identifies the older person as the source of the stress. As of mid-2005, there is no support for this theory.

Social Exchange Theory

Social exchange theory is based on the assumptions that social interaction involves an exchange of rewards and punishments between people, and that all people seek to maximize rewards and minimize punishments. In most relationships, people have different degrees of access to resources and different capabilities to provide services to others, which makes some people more powerful than others. In the social exchange perspective it is argued that, as people age, they become more powerless, vulnerable, and dependent on their caregivers, and it is these characteristics that place them at risk for abuse. There are many problems with this perspective, not the least of which is its basic ageist assumption: people do not automatically become dependent and vulnerable as they age. As noted previously, it is the abuser's sense of powerlessness that leads to maltreatment. Interventions prompted by a social exchange analysis would first have to identify the dependent party. If the older person was assessed as the dependent one, then services aimed at increasing his or her independence would be in order, whereas a dependent adult child might need help from mental health services or require vocational training or job placement in order to become self-reliant.

Social Learning Theory

There is some evidence to suggest that children learn through observation and participation that violence is an acceptable response to stress. Having learned violent behavior, a significant number of children are violent toward their own children and spouses in adulthood. This transmission of violent behavior may be reinforced by a family subculture that accepts and condones violence. While this a popular hypothesis in the literature on family violence, very few elder abuse studies have actually found evidence to support the idea that children who were mistreated by their parents went on to abuse the parents in later life. In fact, several studies have clearly found no basis for the relationship. The small number of studies of this theory (approx two) indicates that further research is required to test this hypothesis.

Political Economy Theory

Research has been preoccupied with the abused and the abuser at the expense of exploring the wider implications of the structure of the economy, the impact of social policy, or factors that systemically organize society such as age, gender, race, ethnicity, and class. All of these societal factors influence people's position in the social structure and their opportunities in life. Some theorists have focused on ageism as a possible factor leading to what some consider a weak political response to elder abuse in various countries and as one of the factors leading to elder abuse (*see* Ageism and Discrimination). For example, older people can be subject to discriminatory attitudes and actions that are based on negative perceptions about their chronological age. Experts have proposed that such ageist attitudes toward older people may contribute to the development of elder abuse. Misconceptions and distortions about aging dehumanize older persons, making it easier for them to be victimized and easier for the abusers to feel little or no remorse. At the same time, elderly people may even view the maltreatment as deserved, since they too may have adopted society's negative attitudes. The feminist models also supply an account of the structural factors: gender determines a set of positions in society that facilitate, and even justify, the abuse of women. Other crucial factors that are known to influence the aging process, such as race, ethnicity, and socioeconomic status, are only now attracting modest attention. As would be expected, the few investigations that do exist show that elder abuse is viewed quite differently by different cultures.

Overall, most scholars have realized that there is a broad diversity in the manifestations of elder abuse and neglect and have abandoned their search for a comprehensive, all-inclusive explanation of the phenomena. In the future, new theories of elder abuse may explain different dimensions of elder abuse and

neglect, and theoreticians will probably cast their net wider, including gerontological theories alongside the family violence theories that have been, so far, the mainstay of the elder abuse literature. As a consequence, practitioners will have a wider array of interventions at their disposal, which will facilitate the provision of more effective care for mistreated elders.

Responses to Abuse and Neglect

National Responses to Elder Abuse and Neglect

Efforts to spur social action to eradicate elder mistreatment at a national level and to develop national polices and legislation are at varying stages of growth around the world. While the United States has developed a full-blown national response to elder abuse at the state level that allows for the funding and reporting of elder abuse and has instituted at least three national organizations (the National Center on Elder Abuse, the National Committee for the Prevention of Elder Abuse, and the National Association of State Adult Protective Services Administrators); other countries have been less proactive.

In Australia and Canada, various states and provinces have created mechanisms for dealing with elder abuse, but there are no firmly established federal policies about elder abuse. At the federal level, both Canadian and Australian national clearing houses on family violence are maintained, while New Zealand has run pilot projects across the country. All three countries have national organizations dedicated to the amelioration of elder abuse that were established in the 1990s. In the United Kingdom there is a national body called Action on Elder Abuse that has stimulated government responses to elder abuse. Norway has had parliamentary approval for services and a resource center for research and information. France, Germany, Italy, and Poland are at the point of recognizing the legitimacy of elder abuse and neglect.

The Latin America Committee on Elder Abuse has been active in drawing attention to the problem within Latin America and the Caribbean. In Buenos Aires, the organization Proteger, a government department, deals exclusively with elder abuse cases and provides staff with training in gerontology. In Brazil, the Ministry of Justice, Health and Welfare supports official training about elder abuse. In Chile, a law against family violence was passed in 1994 that clearly addressed abuse of the elderly.

In Asia, there have been several studies by researchers in Japan, India, and the Republic of Korea about elder abuse and the beginnings of national organizations to fight the problem.

South Africa established a preventive program on institutional abuse that was jointly sponsored by the government and the private sector in 1994, while the Nigerian Coalition for the Prevention of Elder Abuse facilitates the meetings of professionals working with the elderly.

Given this rapid global expansion of activities on elder abuse, the International Network for the Prevention of Elder Abuse (INPEA) was formed in 1997 with representations from six continents. Most recently, the World Health Organization (WHO) recognized the need to develop a global strategy for the prevention of elder abuse. Working with INPEA and HelpAge International, the WHO carried out a study of eight countries (Argentina, Austria, Brazil, Canada, India, Kenya, Lebanon, and Sweden) that used focus groups with older persons in the community and health-care workers to explore their views on elder abuse.

Legal Responses to Elder Abuse

Most countries have not introduced specific legislation on elder abuse. Abuse is often covered under criminal law, or by laws dealing with property rights, civil rights, and family violence or mental health, and varies widely from country to country. In all countries, however, a key issue is whether and under what circumstances criminal charges should be filed against alleged perpetrators. There is a concern as to whether appropriate assistance and support services will be made available after authorities have intervened in a mistreatment case, and considerable concern as to whether the older person will press charges, especially against a family member. A few western countries have introduced special adult protection legislation at the state or provincial level in response to the problem of elder abuse and neglect. The goal of the legislation is to protect the mistreated person, help the abuser, and marshal health and social services.

Adult protection legislation has been largely borrowed from child protection legislation, which called for the mandatory reporting of suspected cases of abuse. This legislation generally falls into three categories: (1) adult abuse legislation with mandatory reporting; (2) elder abuse legislation with mandatory reporting; (3) adult or elder abuse legislation with no mandatory reporting. Adult abuse legislation is applied to persons over the age of 18, but is often restricted to those suffering from physical and cognitive impairments. Elder abuse legislation is directed specifically to older people, usually defined as individuals over the age of 60 or 65. While all 50 states of the United States have legislation authorizing

the state to protect and provide services to vulnerable or incapacitated adults, other countries have been slower to enact special legislation. For example, in Canada only five provinces and one territory have enacted adult protection legislation, while the United Kingdom and Australia have no provisions at all.

Mandatory reporting, the legal obligation to report cases of elder abuse, is the standard in the majority of jurisdictions in the United States, in the Atlantic provinces of Canada, and in Israel. The obligation is usually imposed on certain individuals, such as nurses, doctors, the police, and social workers. The purpose of the legislation is to deter elder abuse and neglect and also to provide a mechanism for collecting data and monitoring prevalence and incidence rates. The legislation frequently grants the reporting individual immunity from civil and criminal liability in order to encourage individuals to report. Failure to comply with mandatory reporting laws can result in fines, civil liability for damages, reports to professional licensing boards, and short jail terms.

The few research studies on mandatory reporting (all done in North America) have cast doubts on the contribution the process can make to the prevention of elder abuse and neglect. Several studies have shown that cases reported under mandatory provisions were already known to the authorities, implying that there is no significant increase in the reporting of cases. In contrast, several studies have shown an increase in the number of cases reported, but also an increase in the number of unsubstantiated cases. Other studies have shown that the statutes failed to ensure the consistent collection of information that would aid in the tracking of the types and extent of abuse and neglect. There is confusing research as to what types of cases mandatory reporting is likely to uncover. Several studies have found that mandatory reporting is more likely to be associated with cases of neglect and self-neglect; others, however, established that mandatory reporting is more likely to be associated with cases of physical abuse. The few studies that examined the relationship between mandatory reporting and institutionalization of the older victim indicated that mandatory reporting could result in increased rates of institutionalization of the abused, although contact with protective services was the more plausible explanation. Finally, the passage of a mandatory reporting law does not necessarily mean that those who are required to report will be aware of the law or be motivated to comply. The general conclusion in the research literature is that mandatory reporting systems in existing jurisdictions need further investigation as to their effectiveness.

Program Responses

A program provides a blueprint for service delivery, establishes resources, and coordinates the delivery of service through government and/or private and public agencies. Three major programs have emerged in response to elder abuse: the statutory adult protection service programs, programs based on the domestic violence model, and advocacy programs for the elderly. A fourth model now appearing in many communities is the interdisciplinary team model. Institutions have been slow in their responses to elder abuse, but promising approaches are appearing, at least in North America. It is not useful to categorize the various health and social services available to older persons, since each program ultimately makes use of them all, depending on need.

Adult Protection Programs The adult protection legislation provides the legal framework for protective services for vulnerable adults. The mandated services are provided in approximately three-quarters of the states in the United States by special adult protection units in state social service departments and, in most of the remaining states, by state units on aging. In Canada, there are at least three different models for service delivery, depending on the provincial jurisdiction. As would be expected, there are great variations in responses, depending on the financial commitment of the state and other organizational and political factors.

The legislation confers a wide range of powers of intervention, which vary from jurisdiction to jurisdiction. The usual procedures for the state or provincially designated units are to receive reports of suspected cases of abuse, to screen the cases for potential seriousness, to conduct an investigation if mistreatment is suspected, to develop a care plan that will resolve the abuse, and then to transfer the case to other community agencies for case management and the delivery of services. The protective services program represents a mixture of legal, health, and social services that allows for the widest array of interventions and for considerable coordination and interdisciplinary team work. Many adult protection workers have had specialized training in the substantive area of elder abuse and neglect. New and innovative learning initiatives are increasing: for example, the creation of a special student training unit within adult protective services was recently instituted for the first time in the United States with considerable success.

In recognition of the fact that not all clients will voluntarily accept protective services, the protection workers may implement guardianship or

conservatorship to ensure that the older person receives the necessary services. Some jurisdictions in the United States have created special court procedures to secure court orders for protective services, to place the client in a nursing home, to provide emergency treatment when the client is in danger, and to enter a client's home against the client's wishes. Proponents of these wide-ranging interventions argue that the rights of the older person are always safeguarded; the goal is to enhance the individual's level of functioning while protecting them from injury. They also maintain that because little can be done for the victim who refuses services (about 36 to 40% of elders refuse services), only mandated interventions ensure that the victim receives at least the minimum help. In addition, such interventions are limited by prudence: few practitioners are willing to risk intervention unless they are on solid legal ground.

Those against an enforcement-oriented approach to service provision dispute these claims. They observe that the vagueness of the legislation in many jurisdictions places adult protection workers in a quandary the moment they try to decide whether abuse has occurred. It is almost impossible to use legal powers to force oneself into an older person's home and at the same time respect the person's basic rights; the protection worker can easily come into conflict with both the older person and the abuser. In addition, adult protection workers have been accused of being 'trigger-happy' in placing older persons in nursing homes and in treating older people as if they were children – an unavoidable occupational hazard given the child welfare roots of the adult protection programs.

Domestic Violence Programs The domestic violence model for program delivery is an adaptation of the programs that have been instituted to combat woman abuse. This approach is gaining momentum in North America, because it does not violate people's civil rights, nor does it discriminate on the basis of age. The domestic violence response to elder abuse involves crisis intervention services, such as telephone hotlines; a strengthened role for police when pressing charges; court orders for protection; the use of legal clinics, emergency, and secondary sheltering; support groups for both the abused and the abuser and individual and family therapy; and the use of a whole range of health, social, and legal services. An integral component of domestic violence services is public education, especially the education of the abused about their rights. Almost all of these services have been adapted specifically for elder abuse victims, and sometimes for their abusers. For example, existing shelters have been modified to accommodate older abused women, and new shelters have been established to accommodate both men and women. Along with shelters, there are support groups, hotlines, special legal clinics, and family and individual counseling programs. An example of each type of service can be found in North America; however, most attempts at service delivery have been scant and sporadic and have shown little evidence of coordination. Whether the model is effective in helping the older victim is still a moot question.

The domestic abuse model is not without its critics, who quickly point out that the flaws in the model equally apply to elder abuse. Problems with police response, restraining orders, poorly managed shelters, and the shortage of follow-up services are but a few of the issues. Gerontologists have also cautioned against the singular use of crisis intervention, since older persons' problems tend to be multiple and interrelated, take a long time to solve, and need to be monitored closely. They also have drawn attention to the inadequacy of the model when applied to cases of neglect. Police intervention or education about rights are inappropriate in the face of family or self-neglect.

Advocacy Programs Advocacy includes all actions performed on behalf of an individual or group in order to ensure that their needs are met and their rights are respected. Like the domestic violence model, this approach recognizes that the older person is an adult in a potentially dangerous situation. Advocates for the abused use the least restrictive and intrusive interventions into the older person's situation. In practice, advocates advise clients of their rights and the alternative services available, and they can assist them in carrying out agreed-upon plans. The most important feature of the advocacy model is the advocate's independence from the formal delivery system; this distance allows the advocate to establish a positive relationship with the older person. Formal and informal advocacy programs are used in a number of states and provinces in the United States and Canada; they operate in the community or in institutions and nursing homes. Although advocacy may appear to be non-intrusive, some social scientists have suggested that, in practice, it can be quite intrusive, especially if the advocate is immune from liability and is not accountable.

The Multidisciplinary Team Model An observable trend at the community level has been the development of multidisciplinary teams made up of workers from a broad array of agencies that represent all of

the programs described previously. These community-based teams or committees provide consultations on atypical and difficult cases of abuse, help to resolve agency disagreements, identify system improvements, and provide services, such as legal and medical consultations not readily available in the community. In some instances specialist teams have been developed, such as the financial abuse specialist teams (FASTs) to investigate financial abuse and the fatality review teams to review deaths brought about by elder abuse and to determine how to prevent further deaths from abuse. Initial assessments of this approach have been very positive: service providers become familiar with one another, resources are organized and dispersed in a single initiative, and more comprehensive care plans are produced. The main drawback reported by team members is that the committees spend more time per case than professionals acting alone.

Residential Care Facilities While residential care settings in most countries are subject to different regulations and enforcement strategies such as unannounced regulatory visits, video recorders in key locations, and ombudsmen, several avenues for intervention have been identified to prevent institutional maltreatment. Interventions that address hiring and the supervision of staff, staff training, and staff skill development, including the problems of burnout and the creation of specialized treatment programs for the abused in an institution, could serve as the basis for managerial initiatives. To date, however, there are few programs and very little research as to what is effective.

Services

It is evident from the literature that the services already available to older persons provide the bulk of the resources used in response to elder abuse, regardless of what approach is utilized, and that new or uniquely designed services are not always required. Most elder abuse practitioners face difficulties in accessing limited resources, especially in critical emergency situations, and they must deal with the challenges of coordination and collaboration in the existing patchwork of services. They also must deal with the reality that there is a paucity of well-researched intervention studies to inform the identification and management of elder mistreatment.

See also: Ageism and Discrimination; Caregiving and Caring; Health Care and Services.

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Accelerated Aging

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Glossary

Accelerated Aging – Characteristic of animals in which the first inflexion on the mortality curve occurs at the same age as in wild-type individuals, but whose mortality after that point occurs at a faster rate.

Free Radical Hypothesis – Proposes that aging is the result of damage to macromolecules, including DNA, occurring because of continuous exposure to free radical species, primarily reactive oxygen and nitrogen species (ROS and RNS, respectively).

Mutation Hypothesis – Proposes that aging is the result of irreparable and irreversible damage to DNA, by whatever means the damage might occur.

Premature Aging – Characteristic of animals in which the first inflexion on the mortality curve occurs earlier than in wild-type animals, but the mortality after that point occurs at a normal rate.

Progeria – A disease causing premature appearance of a significant number of age-associated phenotypes, and usually leading to premature death.

Progeroid – A disease causing premature appearance of a significant number of age-like phenotypes, and usually leading to premature death.

Introduction

In the last few years, much knowledge about aging has been gained from the study of genetically altered organisms, ranging from yeast to mice. Most of the progress has been made by focusing on long-lived mutants, which has allowed the identification of several longevity assurance genes (LAGs). Recently, there have been a handful of publications extolling the virtues of short-lived mutants. These are much more controversial, but when analyzed carefully, they may be just as informative as the long-lived ones. This article describes some of these mutants and discusses their potential uses and pitfalls. The discussion is limited to mice, for which there is enough pathological data, and the mutants are divided into three (subjective) categories: (1) mouse models of segmental progeroid syndromes, (2) mice created to prove or disprove a given hypothesis of aging, and (3) mice that display apparent acceleration of the aging process, but that were created without that expectation in mind.

The golden rule of genetic models of aging (*see* Models of Aging: Vertebrates) is that experimental manipulations that result in an extension of health span are likely to be more informative about the aging process than those that reduce life span (**Figure 1**). This argument is difficult to dispute. However, this article brings forth the argument that short-lived mutants can also be very informative about the aging process, if used and analyzed judiciously. Of course, judiciousness is also a must when dealing with long-lived mutants, since not all longevity-prolonging manipulations are necessarily informative to the aging researcher. Nevertheless, it is recognized that this is even more true in the case of short-lived mutations or manipulations, since many genetic alterations will result in shortened life spans, or even mortality *in utero*, without being informative about the aging process. In fact, most alterations will not be informative. However, in a few cases, it can be argued that such mutants could indeed be useful, as long as the short life span is accompanied by an earlier or faster appearance of a significant subset of the pathologies and age traits characteristic of the species in question. This precludes the use of an important part of the bestiary currently used in aging research, since in the case of *Drosophila melanogaster, Caenorhabditis elegans*, yeast, and other such lower species, we lack sufficient knowledge of their pathology and causes of death, and thus, it becomes impossible to ascribe the short life span of any given mutant to true age-related phenomena. However, in the case of mice, humans, and other higher vertebrates, the pathology and causes of death are better understood, and thus, the use of mutants with shorter life spans becomes a possibility. For the rest of this article, the discussion is limited to genetically modified mouse models, and although very relevant to aging research, the focus is on models that are believed to affect the aging process as a whole, and not the development of specific diseases, even if they are age dependent, such as Alzheimer's or Parkinson's.

There are three main categories in which short-lived genetic variants might be useful for understanding the phenomenon of aging (**Table 1**). First, mouse models of human progerias allow investigators to dissect the molecular mechanisms behind the disease phenotype. There is an argument about whether or not human progeroid syndromes are informative of normal aging, and in that sense, the mouse models

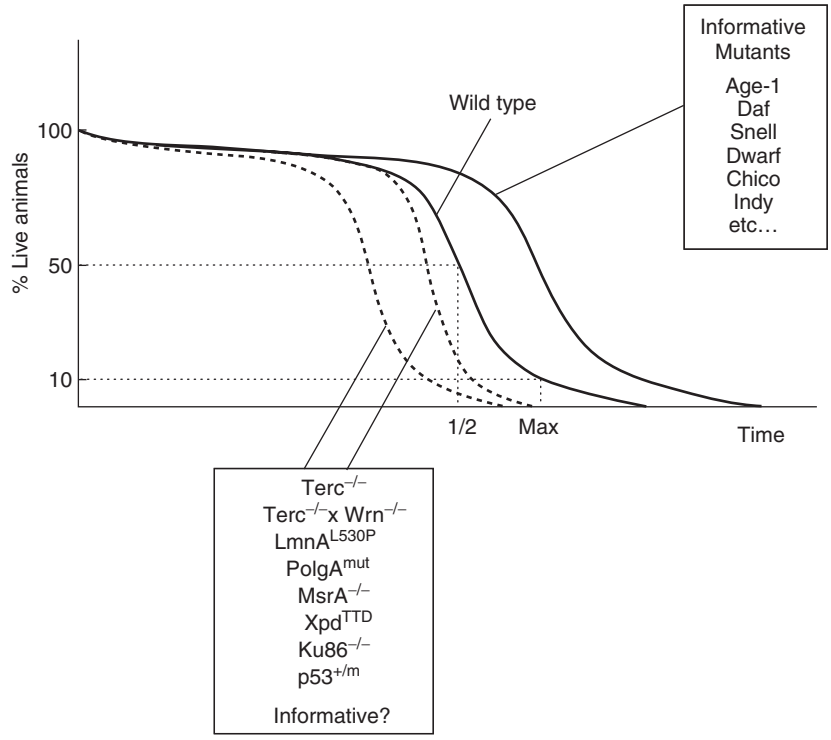

Figure 1 The golden rule of genetic studies of aging. Genetic manipulations believed to affect the aging process usually begin by measuring a surrogate marker of aging, namely, time of death. By measuring survival of a cohort as a function of time, a curve can be drawn from which the mean (50%) and maximal survival (often 10%, but in many cases, the actual longevity of the record holder is reported) can be derived. Mutants that increase both mean and maximal life span have traditionally been automatically considered to be informative of the aging process. Short-lived mutants (broken lines) can be of two types: accelerated aging occurs when the slope of the mortality curve is increased, while premature aging occurs when the curve is displaced to the left without changing the slope. Of course, mixed phenotypes can also be observed.

represent a circular argument. However, most researchers agree that useful information can be derived from these studies, and the mouse models at hand generally confirm this suspicion. Second, several mouse models have been produced in order to test a particular hypothesis of aging. While such mutants might not represent the final answer (and theories of aging have been historically hard to completely dismiss), it is reasonable to suspect that in this case, short-lived mice should be as informative as long-lived ones. Third, there are a few mice in which an accelerated aging phenotype was not expected, yet was observed. To the extent that these can be validated, they are probably the most exciting models.

Mouse Models of Human Segmental Progerias

In 1979, George Martin coined the term segmental progerias to define a series of pathologies characterized by shortened life spans, but most importantly, accompanied by a plethora of early signs of aging, both externally and at the pathological level (*see* Premature Aging). The relevance of these diseases to the study of aging has been challenged, primarily because of the segmental nature of the phenotypes. Conversely, it can be argued that this segmental feature is precisely what makes the models particularly useful, as it allows the dissection of some of the many components that together comprise the complex aging phenotype. Furthermore, the segmental argument also applies to simple models that are either primarily postmitotic (*C. elegans*, *Drosophila*) or unicellular (yeast). The effects of individual genes on longevity must by necessity also be segmental in these cases, since it is extremely unlikely that all features of vertebrate aging can be reproduced in a model organism that either does not contain replicative cells or is unicellular. Furthermore, as is true for all models to be discussed here, it is highly unlikely that aging is controlled by a single or even a small handful of genes. Thus, it is to be expected that specific mutations might have segmental effects, thus affecting some of the aging phenotypes, but not all. And yet, most researchers will agree that models of increased longevity have been very useful, and their usage has outlined the importance of several pathways (the IGF

Table 1 Short-lived mouse models with possible relevance to aging research

Model	*Gene*	*Function*	*Median life span (% of wt)*[a]	*Reference*
Terc$^{-/-}$ G5-G6[b]	*Telomerase*	Telomere maintenance	75	Blasco *et al.*, 1997
Terc$^{-/-}$ *x Wrn*$^{-/-}$ G3	*Telomerase + Wrn*	DNA helicase	45	Chang *et al.*, 2004
Terc$^{-/-}$ *x ATM*$^{-/-}$ G3	*Telomerase + ATM*	DNA damage sensor	50	Wong *et al.*, 2003
Terc$^{-/-}$ *x Wrn*$^{-/-}$ *x ATM*$^{-/-}$ G3	*Telomerase + Wrn + ATM*	DNA helicase, DNA damage sensor	30	Du *et al.*, 2004
LmnA^{L530P}	*Lamin A*	Nuclear architecture	20	Mounkes *et al.*, 2003
PolgA^{mut}	*DNA polymerase* γ	Mitochondrial DNA synthesis	45	Trifunovic *et al.*, 2004
MsrA$^{-/-}$	*Met sulfoxide reductase*	Repair of oxidized proteins	60	Moskovitz *et al.*, 2001
Xpd^{TTD}	*X pigmentosa gene D*	DNA repair (NER)	50	De Boer *et al.*, 2002
Ku86$^{-/-}$	*Ku 86*	DNA repair (NHEJ)	35	Vogel *et al.*, 1999
p53$^{+/m}$	*p53*	Checkpoint, apoptosis, senescence	80	Tyner *et al.*, 2002
p44	*p53*	Checkpoint, apoptosis, senescence	30	Maier *et al.*, 2004
kl$^{-/-}$	*Klotho*	Hormone	35	Kuro-O *et al.*, 1997
SAM	Unknown	Unknown	Variable	Takeda *et al.*, 1981

[a] Approximate, as a percent of wild type for the strain.
[b] G, generation.
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pathway and sirtuins, for example), as well as the importance of stress resistance to longevity. Importantly, further experimentation has shown the validity of several of these observations in higher vertebrates including mice. In these examples, therefore, the segmental argument loses its validity.

There are multiple diseases that, to varied extents, can be classified as segmental progerias, and recent research has identified the culprit genes in most of them (**Table 2**). In all cases, they turned out to be genes involved in nucleic acid metabolism, thus lending strong support to the so-called mutation hypothesis of aging. The most dramatic is childhood progeria, or Hutchinson-Gilford syndrome (HGS). In this case, the mutation affects the structural nuclear envelope protein Lamin A (LmnA), and the defective processing of this molecule leads to significant changes in nuclear morphology and function. Thus, cells from these patients are very prone to apoptosis and are also resistant to immortalization by telomerase. Accordingly, affected children die in their early teens, usually of cardiovascular disease. A mouse model of defective LmnA shows a comparable extremely short life span as well as a considerable set of age-related diseases and phenotypes (**Table 3**). Thus, even though the mutation present in this mouse is not exactly the same as in HGS, the mouse does recapitulate many aspects of this most dramatic progeria. Several laboratories have produced true HGS mice, but their characterization is still very incomplete and unpublished.

Mouse models of several other progeroid syndromes, including Werner, Bloom, ataxia telangiectasia, and several members of the xeroderma pigmentosa pathway, have also been produced. Interestingly, with the exception of the *Xpd*^{TTD} mouse (a model for the disease trichothiodystrophy [TTD], discussed later), all of the others failed to present any phenotype, including accelerated aging. At least in the case of Wrn, Blm, and Atm, the cause for this lack of phenotype has been established after further scrutiny. Both *Wrn* and *Blm* code for DNA helicases, while Atm plays a critical role in the activation of the stress response after DNA damage (**Table 1**). All three

Table 2 Human progeroid syndromes, their genes, and corresponding mouse models

Syndrome	*Gene*	*Mouse model*	*Median life span*[a]	*Reference*
Werner	*Wrn*	*Terc*$^{-/-}$ *x Wrn*$^{-/-}$ *G3*	67/45	Chang *et al.*, 2004
Bloom	*Blm*	*Blm*$^{-/-}$	33/Embryonic lethal	Chester *et al.*, 1998
Hutchinson-Gilford	*LmnA*	*LmnA*^{L530P}	17/20	Mounkes *et al.*, 2003
Ataxia telengactasia	*ATM*	*Terc*$^{-/-}$ *x ATM*$^{-/-}$ *G3*	35/50	Wong *et al.*, 2003
Xeroderma pigmentosa	*XP A-G*	*XPD*^{TTD}	5/50	De Boer *et al.*, 2002
Cockayne syndrome	*CSA, B*	*CSA*$^{-/-}$ *CSB*$^{-/-}$	65/100	Lu *et al.*, 2001

[a] As percentage of wild type. Human/mouse model.

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proteins are at least partially found in association with telomeres, and it was therefore surmised that the lack of a phenotype might be due to the excessively long telomeres present in mice, as compared to humans. Interestingly, like the others just mentioned, *Terc*$^{-/-}$ mice also failed to show any immediate phenotype. However, upon repeated cross-breeding, *Terc*$^{-/-}$ mice did show accelerated age-related pathology and shorter life spans, albeit at the fifth or sixth generation, supposedly because their telomeres had been humanized by shortening (**Table 3**). By crossing *Wrn*$^{-/-}$, *Blm*$^{-/-}$, and/or *Atm*$^{-/-}$ mice with *Terc*$^{-/-}$ mice, the resulting double and triple animals did display accelerated aging phenotypes at much earlier generations (usually the third), and furthermore, some of the phenotypes observed were not present even in later generation *Terc*$^{-/-}$ mice. These data indicate that mutations in these genes can indeed give rise to an accelerated aging phenotype, as long as the telomeres are not excessively long. The data also suggest that the proteins participate in protecting cells from the effects of dangerously short telomeres.

Werner is the best characterized of the human progeroid syndromes, and so are the double (*Wrn*$^{-/-}$ x *Terc*$^{-/-}$) and triple (*Wrn*$^{-/-}$ x *Atm*$^{-/-}$ x *Terc*$^{-/-}$) knockout mice, so the rest of the discussion will focus on these models and how they have demonstrated their usefulness in aging research. Mutations in the *Wrn* gene lead to two major effects: a mutator phenotype (given primarily by stalling at replication forks) and accelerated cellular senescence. Clinically, Wrn patients show a rather dramatic skin atrophy phenotype in the presence of a normal immune system (*see* Premature Aging). Further analysis indicates that while the mutator phenotype of *Wrn*$^{-/-}$ is observable in both skin fibroblasts and T lymphocytes, accelerated senescence is observed only in fibroblasts, not in lymphocytes, which have higher telomerase levels, at least in young individuals. These observations suggest that cell senescence, rather than mutations, might be more closely related to the agelike phenotype of the skin of Wrn patients, but further confirmation is difficult in the absence of a tractable genetic model of the disease in a lower organism. Thus, the mouse models have helped: fibroblasts from *Wrn*$^{-/-}$ mice (which, as we have seen, do not show any pathology) do not show premature cellular senescence either. In contrast, fibroblasts derived from third-generation *Wrn*$^{-/-}$ x *Terc*$^{-/-}$ mice (which do show age-related pathology) do undergo premature cell senescence and are also more sensitive to apoptosis. In fact, both of these phenotypes have also been observed *in vivo* in later generation double- or triple-mutant mice. These observations further confirm that it is cellular senescence (or at least a DNA transaction occurring at telomeres) that is responsible for the observed phenotypes. It should be pointed out that conversely, Wrn patients suffer from other pathologies that are not age related, such as increased mesenchymal tumors, rather than the epithelial tumors most commonly found among the elderly. This effect might be the result of the mutator phenotype of *Wrn*$^{-/-}$ cells. Such an explanation would predict that in a normal subject, the Wrn protein might protect the mesenchymal cells more efficiently than the epithelial cells. Taken together, these observations suggest that (1) the DNA transactions that involve Wrn, Blm, and Atm are most relevant at the level of the telomeres, (2) telomere biology indeed seems to be important in aging, as previously suggested by research on cellular senescence, and (3) the lack of a phenotype in the earlier generation mice, or in mice with wild-type Terc, suggests that the mutator phenotype conferred by mutations in proteins such as Wrn is not relevant for aging.

Table 3 Accelerated aging phenotypes in selected mouse models

Phenotype	*Terc*$^{-/-}$ *G5-G6*	*Terc*$^{-/-}$ *x Wrn*$^{-/-}$ *G3*[a]	*LmnA*^{L530P}	*PolgA*^{mut}	*MsrA*$^{-/-}$	*Xpd*^{TTD}	*Ku86*$^{-/-}$	*p53*$^{+/m}$	*p44*
Stunted growth	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lordokyphosis/osteoporosis	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Alopecia/hair thinning	Yes	nr	Yes	Yes	nr	Yes	Yes	No	nr
Fragile skin/wound healing	nr	Yes	Yes	Yes	nr	nr	Yes	Yes	nr
Premature infertility	Yes	Yes	Yes	Yes	nr	Yes	Yes	No	Yes
Muscle atrophy	nr	nr	Yes	Yes	nr	Yes	nr	Yes	nr
Subcutaneous adiposity loss	nr	nr	Yes	Yes	nr	nr	nr	Yes	nr
Cardiovascular defects	nr	nr	Yes	Yes	nr	No	nr	nr	nr
Stress resistance	Low	nr	nr	nr	nr	nr	nr	Low	nr
Tumor development	Increased	Mesenchymal	N/A	nr	nr	Normal	Increased	Decreased	Decreased
Apoptosis	Yes	Yes	nr	nr	nr	nr	Yes?	Yes	nr
Accelerated cell senescence	Yes	Yes	Yes	nr	nr	Yes	Yes	Yes	Yes
Increased genomic Instability	Yes	Yes	nr	Yes	nr	Yes	Yes	nr	nr

[a] As a representative of other models of human progeroid syndromes.
nr, not reported; N/A, not applicable.

Mouse Models that Test Hypotheses of Aging

The field of aging has been prolific in producing theories that are elusive to prove, but also difficult to disprove. Genetics provides a powerful means to test hypotheses, and such an approach has indeed been used by researchers in the aging field. In simple terms, if a gene or a process is hypothesized to play a role in aging, then overexpression of that 'bad' gene should result in accelerated aging, while knocking the gene out or inactivating it should result in increased longevity and/or less age-related disease. Of course, the opposite is true for a 'good' gene.

Two of the most pervasive theories of aging are the free radical hypothesis and the mutation hypothesis. To an extent, these are intimately connected, because one of the central tenets of the free radical hypothesis is that free radicals, produced either intrinsically or extrinsically, will ultimately damage the DNA, leading to some nebulously explained molecular catastrophe that results in tissue deterioration, disease, and finally death. Both of these theories have been tested rather extensively in mouse models. Most notably, with the possible exception of mitochondrial-directed catalase, overexpression of several enzymes involved in scavenging free radicals failed to provide an extension of life span, as did the overexpression of enzymes involved in DNA repair. The proponents of these theories offer many arguments to explain these disappointing results, including an already available overabundance of protection against free radicals, or the enormous complexity and potential for functional redundancy in DNA repair systems. Some of these arguments might be true, and some researchers have therefore turned to the opposite approach: deletion of these protective and/or repairing genes should produce a shorter life span.

Testing the Free Radical Hypothesis of Aging

More than 40 years ago, Clark and Rubin showed that radiation leads to a shortening of the life span. This is a manipulation that in many respects is akin to a genetically short-lived mutant mouse. However, instead of being dismissed as irrelevant to aging, such experiments spawned what is currently the most accepted hypothesis of aging: the free radical hypothesis. The hypothesis was originally proposed by Denham Harman in 1956. It predicts that aging results from the accumulation of damage to macromolecules produced by reactive oxygen species (ROS) or other free radical species. ROS are produced both intrinsically, primarily in the mitochondria and the plasma membrane, and extrinsically, by reactive compounds present in the diet and the environment. Because of their enormous potential for damage, cells have evolved powerful means of neutralizing free radicals, primarily through scavengers, both cellular and from the diet. The best characterized cellular ROS scavengers are the superoxide dismutases (SODs). Because most of the free radical generation appears to arise from mitochondrial respiration, and both free radicals and their associated damage appear to increase with age, much effort has been focused on the mitochondrial MnSOD. Overexpressing the enzyme did not result in an extension of life span, and the knockout is embryonic lethal. Thus, further studies have been done on heterozygous mice. These animals indeed display a 50% reduction in MnSOD activity, without a compensatory upregulation of other scavengers, including the peroxysomal Cu/ZnSOD, catalase, or glutathione peroxidase, Gpx. They show increased ROS production in several tissues analyzed, and this does indeed lead to increased oxidative damage to both nuclear and mitochondrial DNA and to lipids, as well as increased pathology (primarily cancer). Surprisingly, however, the mice displayed absolutely no changes in life span. Similar results have been observed for $Gpx^{-/-}$ mice. Together with the data on SOD and catalase overexpression, these data strongly question the validity of the free radical hypothesis of aging, and in this case, it is the lack of a short-lived mouse model that proved to be informative. However, there is a mouse that has a defect in a gene related to free radicals and that is short lived: the $MsrA^{-/-}$ mouse (methionine sulfoxide reductase knockout; see **Table 1**). This mouse appears to be significantly short lived, though the survival study lacked enough statistical power to be conclusive. MsrA is not involved in scavenging free radicals; rather, it reverses the damage that these compounds produce in proteins. Many proteins have an abundance of methionines exposed in their surface, and because all cells have MsrA, which can reverse the oxidative damage caused by ROS on this particular amino acid side chain, this might represent a last line of defense against ROS. If this mouse can be shown to be short lived, it would rescue the free radical hypothesis of aging, but based on all other data available, the hypothesis would need to be revisited.

Testing the Mutation Hypothesis of Aging

The mutation hypothesis of aging assumes that aging is the result of progressive accumulation of damage to DNA, eventually resulting in loss of tissue functionality and the aging phenotype. The hypothesis implies the importance of defense mechanisms in attaining a long life, and indeed, many long-lived

mutants in several animal models are characterized by an increased ability to withstand stress. An emerging generalization is that the ability to either defend the organism against stress or repair the damage effectively after it is produced is a central feature of long-lived individuals, be it at the level of mutants within a species or at the level of comparative biology (i.e., comparison of different species with different life spans). A corollary to this observation is that no specific damage can be blamed directly for the age-related decline. Rather, any damage, if not repaired, will do it.

Several mice with reduced DNA repair mechanisms have been produced. Most of these animals display no change in life span. Among them, most relevant are the $Xpa^{-/-}$ and $Xpc^{-/-}$ mice, because a closely related family member, *Xpd*, does produce an accelerated aging phenotype when mutated (see later). All Xp proteins are involved in base excision repair, and in some cases, their mutation leads to the segmental progeroid syndrome, xeroderma pigmentosa, or to trichothiodystrophy (TTD), also characterized as a segmental progeria. Xpd is primarily involved in transcription coupled repair, a subclass of base excision repair, and it has been proposed that it is this activity that is mainly affected in the mutant mice. A similar situation applies to genes involved in nonhomologous end joining repair (NHEJ) of double strand breaks. This pathway involves several proteins, including Ku70, Ku86, Xrcc4, and DNA ligase IV. Of these, only $Ku86^{-/-}$ mice display premature aging, but such a phenotype has not been observed in any of the other mutants, in spite of the fact that all these mice display premature cellular senescence. Clearly, all of these mice need to be investigated further, maybe in conjunction with $Terc^{-/-}$ mice, as has been done in the case of *Wrn, Atm,* and *Blm*.

As mentioned previously, however, there are two exceptions that deserve discussion, the Xpd^{TTD} and the $Ku86^{-/-}$ mice. In both of these cases, the mice live shorter than wild-type controls (significantly so in the case of $Ku86^{-/-}$ and only marginally in the case of Xpd^{TTD}). Most importantly, the mice display several symptoms of premature aging, including small size, lordokyphosis, and skin and bone deficiencies (see **Table 3**). Thus, like in the $MsrA^{-/-}$ mice, the data suggest that under certain circumstances, failure to repair DNA damage can indeed lead to premature aging.

At first glance, the general inability to obtain short-lived mutants when DNA repair pathways are incapacitated suggests that damage to DNA might be important in certain pathologies, such as cancer, but irrelevant to aging. An alternative possibility is that the integrity of the genome is so important that sufficient defense mechanisms are in place, so that elimination of any repair pathway is efficiently corrected by a backup mechanism. However, in several of these strains, significantly increased levels of DNA damage (up to 30-fold) have been observed, an observation that weakens this second proposition. Similarly, mice that have reduced free radical defense mechanisms, such as $Sod2^{+/-}$, $Cat^{-/-}$, and $Gpx^{-/-}$, show increased levels of DNA damage but no effect in life span. In contrast, the short life span of the $MsrA^{-/-}$ mice, defective in an enzyme responsible for repair of oxidatively damaged proteins, suggests that it is not the ROS-driven damage to DNA that causes a shortened life span but, rather, the damage to proteins. This is contrary to firmly entrenched current beliefs, but the data can be harmonized by proposing that it is not damage *per se* that causes aging, but damage to specific proteins that can act as sentinels and induce a cellular response that is at the center of the action. Some possible targets have been proposed, such as mitochondrial *cis*-aconitase, but experimental testing is still lacking.

One other mouse model that was produced with the intent of testing a hypothesis of aging is the $PolgA^{mut}$ mouse. These animals express a proofreading deficient form of the nuclear encoded catalytic subunit of mitochondrial DNA polymerase. As expected, the mice suffer a severe increase in mitochondrial DNA mutations (3- to 5-fold), and indeed, the mice are significantly short lived and display an early onset of age-related phenotypes (see **Table 3**). This model suggests that unrepaired DNA damage can indeed affect the process of aging, and since the affected DNA is the mitochondrial genome, it neatly links mitochondrial-derived ROS to the DNA damage hypothesis. The discrepancy with other models of DNA repair prompts two alternative explanations: (1) it is the mitochondrial (but not the nuclear) DNA that is important for the aging process, or (2) the redundancy of the repair machinery available in the nucleus (but not the mitochondrion) prevents the other mice from developing a phenotype. As discussed earlier, the fact that most of these mice do display vastly increased levels of DNA damage argues against the second hypothesis, and thus the mitochondrial DNA emerges as a strong candidate.

In summary, mice produced with the purpose of testing specific theories of aging have yielded mixed results. Because the research has been hypothesis driven, well-done experiments are informative even if a short-lived mouse is not obtained. Indeed, the inability to obtain such mice informs us about the validity of the hypothesis, and the negative result, if

well obtained, begs for a revision of the hypothesis in order to properly accommodate the data.

Mouse Models with an Unexpected Accelerated Senescence Phenotype

In 2002, a paper by Tyner *et al*., showed that a serendipitously obtained p53 mutant in mice, dubbed $p53^{+/m}$, confers a shorter life span accompanied by a considerable premature aging phenotype that includes the usual small body size, lordokyphosis, and skin and bone deficiencies, as well as several other symptoms of aging (see **Table 3**). The mouse was obtained by a fortuitous incorrect recombination event that led to the deletion of several genes upstream of p53, but most notably, it also produced a deletion of the amino terminus of the p53 protein, which contains the transcriptional activator domain. The truncated carboxyl fragment contains the polymerization domain, and thus, it is expected to form heterotetramers with wild-type p53. In fact, the *m* mutation only produces the phenotype in the presence of a wild-type p53, suggesting that it is the heterotetramers that are the active species. p53 is a very important tumor suppressor and regulator of cell fate. In response to DNA damage, p53 activation leads to a cell cycle arrest that gives the cell a chance for repair. If that does not occur, then p53 can induce one of two pathways that remove the affected cell from the potentially proliferating pool: it can induce either apoptosis or cell senescence, two well-described mechanisms of tumor suppression. Accordingly, overexpression of p53 results in a reduced tumor burden, while mice heterozygous for this gene display a dramatic increase in tumors (and a correspondingly short life span). Most surprisingly, the *m* allele of p53 also reduces tumor incidence (to 6%, from the 45% observed in wild-type mice), but instead of living longer, they live shorter (by 20%) and display accelerated aging. Thus, the mutant appears to act as a hypermorph, increasing the basal activity of wild-type p53. In fact, there is precedence for this, since it has been shown that the p53 mRNA can give rise to two different proteins, p53 and p44, the second being the product of an alternative initiation site for translation, located at an AUG in the fourth exon. p44 has been shown to act as a hypermorph, and mice expressing this alternative protein (in addition to the wild-type p53) have been produced. Like the *m* mutation, these mice also display a shortened life span, accompanied by a plethora of age-related characteristics. Because p53 is involved in cell proliferation, apoptosis, and cell senescence, it was interesting to ascertain the causes for the small size of the animals, a non-aging-related feature common to all accelerated models that might also give a clue as to the causes of early death. In both strains of mice, it was found that several tissues show early atrophy. This is not due to a smaller size of the existing cells; rather, the tissues display a reduced cellularity. Furthermore, embryonic fibroblasts from $p53^{+/m}$ mice display premature senescence and a decrease in the growth burst usually observed during the first passage *in vitro*. Together, the data suggest that the accelerated aging phenotype might be related to the decreased cellularity in a variety of organs, as well as decreased regenerative ability. Consequently, it has been hypothesized that this might be due to p53's ability to reduce cell proliferation, particularly in the stem cell niche, and indeed, the $p53^{+/m}$ mice display a reduced number of hematopoietic stem cells, even at an early age.

While the hypermorphs seem to accelerate aging, simple overexpression of p53 does not. The so-called super p53 mice do indeed show an increased resistance to tumors, but they do not live shorter (or longer, for that matter). It has been hypothesized that the reason for this difference lies in the pulsatility of p53 gene expression. In response to a genotoxic stress, p53 is rapidly induced and rapidly turned off. This mechanism is still in place in super p53 mice, which were generated by insertion of large BACs supposedly containing all relevant regulatory elements normally present in the p53 locus. Thus, super p53 mice contain a supernumerary normal allele, capable of normal but increased pulsating activity. In contrast, it is possible that the presence of hypermorphic variants in both the *m* and the *p44* models leads to a stabilization of active p53 tetramers, resulting in a sustained response. This inability to turn off the signal might be what leads to the decreased longevity, since all cells in the animal are exposed to high levels of p53 activity even after the genotoxic assault has subsided. As mentioned, both $p53^{-/-}$ and $p53^{+/-}$ mice live shorter, but their increased tumor burden (and death from these tumors) makes them poor models of aging. However, a similar argument can not be made for the $p53^{m/+}$ or the *p44* mice. It will be interesting to learn what these mice can teach us about cellular homeostasis and its relation to normal aging.

Accelerated Aging in Mouse Models with Less Defined Genetics

In addition to the models described previously, there are at least two additional models of premature aging in mice, in which the functionality of the gene responsible for the phenotype has not been positively identified. These are the *klotho* mutation and the

senescence accelerated mice (SAM). Mice born with the autosomal recessive mutation *klotho* live less than 100 days and display several age-related characteristics (**Table 3**). Conversely, overexpression of *klotho* in mice extends life span. The mutated gene has been cloned, and a recent report indicates that its product functions as a circulating hormone that binds to a cell surface receptor and represses the intracellular signals derived from insulin or IGF1.

SAM mice are actually a group of several inbred strains, developed from AKR/J mice and selected for accelerated senescence. It has been proposed that these mice might represent better models for progerias than for normal aging. Each strain displays a unique but reproducible subset of aging phenotypes, affecting different organs and functions. In none of them has the culprit gene(s) been identified, although microsatellite marker analysis has indicated the presence of four loci that appear linked to the senescence acceleration. Because the onset of senescent phenotypes is not significantly earlier than controls, these mice appear to represent a model of accelerated senescence rather than premature senescence, as in the case of the human diseases Werner or Hutchinson-Gilford.

Conclusions

Several short-lived mouse strains have been developed recently. The important questions are the following: Are they useful models for studying aging? What can we learn from these mouse models? (Or, perhaps, what have we already learned?) Several researchers have argued that these models are not useful, because there are a myriad of ways of shortening life span without affecting the aging process, and thus, it is extremely difficult to select which ones might be informative from among all these short-lived mice. In contrast, it is often argued or assumed that, for an organism to live longer than the average of the species, the entire aging machinery needs to be modified. Thus, the argument goes, mutations that increase life span must be informative of the aging process as a whole. This is obviously a fallacy. In captivity, the life span of female fruit flies is limited by the accumulation of toxic byproducts present in the male's seminal fluid. Restriction of intercourse or genetic manipulations that decrease such toxicity would greatly increase the life span of female flies, but such manipulations are utterly uninformative about the process of aging. Thus, similar caution is required on both ends of the spectrum, though it is conceded that more caution is required in the case of short-lived models.

One subject that has not been brought up in the previous discussion is the Gompertz curves. It has been frequently argued that mutations that alter life span in any way must conform to Gompertzian traits. That is, the slope of the mortality curve (which represents the age-specific mortality) must be affected in order for the model to be called a true model of accelerated aging. Not all researchers agree with this criterion, and indeed, the Gompertz equation accepts as valid only those models that display accelerated aging, but it precludes the use of models in which aging occurs prematurely but with the same mortality slope (see **Figure 1**). The arguments in both directions are beyond the scope of this article, but nevertheless, the discussion would not be complete without at least mentioning this fact. Gompertz curves have proved very useful in aging studies based on population genetics (primarily *Drosophila*). However, with some exceptions, in most of the models described here the size of the cohorts (dictated by the price of raising mice to an old age) is relatively small, and a proper Gompertz curve can not be confidently derived. Nevertheless, a recent review attempted to distinguish which of these models might be useful to study aging, according to this particular criterion. Based on their analysis, the authors concluded that most of the models described here do not display a change in the slope of the Gompertz equation. The exceptions are the PolgA^{mut} and the MsrA$^{-/-}$ mice. Surprisingly, however, the authors also failed to observe age relevance in several well-established long-lived models, including Prop 1, IGF1R, GHRHR, and InsR. In contrast, they do find a relevant relationship in the cases of GHR, Pit1, and Shc. Given the close relationship between these many models, it seems likely that this criterion might be too stringent, and/or some of the data were derived without sufficient numbers of animals. This is certainly the case for the MsrA$^{-/-}$ mouse.

One potentially useful analysis of the various models involves contrasting the characteristics, at the cellular level, of short-lived mutants and mutants affecting similar pathways, but that do not live shorter. **Table 4** lists a limited number of such comparisons. The pairs (first- vs. third-generation *Wrn*$^{-/-}$ x *Terc*$^{-/-}$; *Xpa*$^{-/-}$ and *Xpc*$^{-/-}$ vs. *Xpd*^{TTD} and *Ku86*$^{-/-}$; *SOD*$^{+/-}$ and *Gpx*$^{-/-}$ vs. *MsrA*$^{-/-}$; and *super p53* vs. *p53*$^{+/m}$ and *p44*) were chosen from those discussed previously. The cellular features compared were limited to DNA damage, cellular senescence, and apoptosis. The table shows that there is little if any correlation between the ability of a given genetic manipulation to increase damage to DNA (or increase ROS production) and shortening of life span. As discussed earlier, one important

Table 4 Comparison of selected phenotypes in accelerated vs. not-accelerated aging mice

Model	*Short lived*	*DNA damage*	*Premature cellular senescence*	*Apoptosis*
Terc$^{-/-}$ *x Wrn*$^{-/-}$ G1	No	Yes	No	No
Terc$^{-/-}$ *x Wrn*$^{-/-}$ G3	Yes	Yes	Yes	Yes
Xpa$^{-/-}$ *, Xpc*$^{-/-}$	No	Yes	nr	nr
Xpd^{TTD} *, Ku86*$^{-/-}$	Yes	Yes	Yes	Yes?
SOD$^{+/-}$ *, Gpx*$^{-/-}$	No	Yes	nr	No/Yes[a]
MsrA$^{-/-}$	Yes	No	nr	nr
Super p53	No	nr	No/Yes[a]	No/Yes[a]
p53$^{+/m}$ *, p44*	Yes	nr	Yes	Yes

[a]Normal under basal conditions, enhanced after stress.
nr, not reported.

exception not included in **Table 4** concerns the *PolgA*^{mut} mice, which do live shorter, apparently as a result of increased damage to their mitochondrial DNA. In contrast, there is good agreement between the increased capacity to undergo either cellular senescence or apoptosis and a shortened life span. In the case of the *Sod*$^{+/-}$, *Gpx*$^{-/-}$, and super p53 mice, increased apoptosis or cell senescence is only observed after appropriate challenges, but not when measured under resting conditions.

Thus, the emerging picture points in the direction of a significant role for basal cellular turnover (under basal conditions) in controlling life span. Indeed, any manipulation that leads to increased cell turnover seems to culminate in accelerated aging. Thus, if cells are suffering a chronic increase in stress loads, be it because they cannot repair their DNA (*Wrn*$^{-/-}$, *Ku80*$^{-/-}$, *Xpd*^{TTD}, *PolgA*^{mut}), or because of structural defects (*LmnA*^{L530P}) or reduced defenses (*MsrA*$^{-/-}$), the end result will be a chronic increase in apoptosis and/or cell senescence. Indeed, further support for a role of apoptosis both in aging and in the accelerated aging phenotype of the *PolgA*^{mut} mouse has recently been published. Thus, the short-lived models are teaching us that it may not be the origin of the damage that is critical, but rather whether or not that damage can be repaired in a way that precludes the functional loss of the cell, be it via apoptosis or cell senescence. Both of these outcomes might lead to an increased pressure on the replicative capacity of stem cells, as was suggested by studies on *p53*$^{+/m}$ mice. If in turn this capacity is also taxed, and/or if the process of stem cell proliferation and differentiation is further affected by the aging milieu, then the end result will be increased aging of the tissue. Because of the effect of surrounding tissues, this process is self-renewing, giving rise to the exponential deterioration observed in aging organisms. Naturally, different tissues will be affected at different rates, and the effects will also be idiosyncratic within the population under study.

See also: Life Span Theory; Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates; Premature Aging; Slowing of Aging; Telomeres.

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Achievement

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Glossary

Career Age – The number of years an individual has been active within a given domain of achievement. Also called professional age.

Equal-Odds Rule – The empirical generalization that the ratio of successful works to total output stays more or less constant across an individual's career.

Last-Works Effects – The tendency for creative products conceived toward the end of life to exhibit qualitative and quantitative changes. These changes suggest a resurgence and transformation of creativity in the final years.

Introduction

Achievement is a generic concept that can cover a tremendous range of human activities. These activities may have little in common and may require rather distinctive biological, psychological, and sociological conditions. To offer some obvious examples, the Nobel laureate in physics may have little in common with the Olympic athlete, just as the founder of a successful business enterprise may share nothing at all with a movie star. However, close examination of these and other cases does reveal that all instances of achievement tend to feature the same four characteristics.

First, achievements are behaviors or products that make an individual stand out from the majority of individuals who are active in the same endeavor. Not every author wins the Nobel Prize for Literature; not every tennis player becomes a singles champion at Wimbledon; not every entrepreneur manages to build from scratch a Fortune 500 company. As these instances show, some individuals may attain distinction by offering something unique to the world, such as an artistic masterpiece, whereas others may make a name for themselves by performing some well-defined task better than any competitors, such as sprinting 100 meters faster than anyone else in the world.

Second, achievements are behaviors or products that reflect favorably on the skill or talent of the person under view. Only a tiny percentage of the population has the mental or physical capacity to make a serious bid for a major honor, award, or prize. It is for this reason that lottery winners are not credited with achievements; the skill needed to purchase a lottery ticket is of a very ordinary kind that everybody possesses.

Third, we usually associate achievement with motivational characteristics, such as effort, persistence, drive, and determination. As a consequence, individuals who enjoy a certain natural talent at some task but who make no attempt to develop their native skills further are most likely to be called underachievers. So important is this third characteristic of achievement behaviors that we will sometimes label an activity an achievement even when it requires far more motivation than ability or skill. For instance, many of the achievements listed in the *Guinness Book of Records* are of this variety. Someone who holds the world record for the number of days spent sitting atop a pole is going to earn admiration more for persistence than for talent. Nevertheless, those achievements that seem to require both

ability and effort seem to elicit the most widespread and profound esteem.

Fourth, the word achievement is normally assigned to behaviors or products that have positive social value. Accordingly, notorious assassinations or infamous crimes are seldom considered accomplishments. Unfortunately, this component of the concept is not always easy to evaluate. Not only may value judgments vary from culture to culture, but these assessments may also vary from individual to individual within the same culture. In some nations, assassination for political or religious reasons may be actually encouraged. And for some pacifists, a general's victories on the battlefield may constitute criminal acts of institutionalized homicide. Nevertheless, nothing prevents us from adopting a relativistic conception of societal norms. If an activity tends to earn praise from the majority of those living within a given sociocultural system, it can be counted as a notable accomplishment.

In this article, the focus is on those achievements that exemplify all of the central characteristics. The key question then becomes how this level of achievement varies as a function of a person's age. At what point can it be safely inferred that a particular individual is 'over the hill' or 'past his or her prime'? Does there exist an age beyond which we should not anticipate further accomplishments of the kind witnessed earlier in the career? To address this question, we first review the empirical findings on this subject. Next we can examine some of the possible theoretical interpretations of those results.

Empirical Findings

The scientific study of the relation between age and achievement is one of the oldest research topics in the history of the behavioral sciences. The earliest such investigation was conducted in 1835 by Adolph Quetelet, who examined how the production of notable plays varied as a function of the dramatist's age. This was the first study to demonstrate how creative productivity often declines in the later years of life. However, the first truly thorough research on this subject was conducted by Harvey C. Lehman, especially as summarized in the 1953 book *Age and Achievement*. Lehman investigated virtually every possible domain of achievement, including both creativity and leadership. He also attempted to introduce much more systematic and rigorous methods in his quest for the typical age curves for various intellectual, aesthetic, political, and economic endeavors. Although subsequent investigators have identified several methodological flaws in Lehman's work, many of the central results have been replicated in studies that use more advanced analytical techniques. In particular, the literature tends to support the conclusion that the odds of significant achievement usually tend to decline after a career peak that most often appears around mid-life. In addition, the specific nature of this descent tends to vary according to many other factors, such as the specific domain of achievement. These and other complications will become apparent in the following sections, where we examine the longitudinal changes in three broad domains: leadership, creativity, and entertainment.

Leadership

Of all categories of achievement, leaders may occupy the highest place. Political, military, economic, and religious leaders all define the world in which we all inescapably must live. A nation's material and emotional well-being closely depends on the politicians who write its laws, the generals who are responsible for defending its boundaries, the entrepreneurs who introduce new products and create new industries, and the religious figures who guide a people's moral and spiritual life. It should not be surprising, then, that of all forms of achievement, leaders tend to be the most prominent. The average person on the street may not know who most recently received the Nobel Prize for Literature or for Physics, but few would not be able to identify the individual who serves as the nation's current head of state. Even the historical reputation of leaders tends to exceed that of individuals active in different domains of attainment.

Given the significance of leadership, the relation between age and achievement assumes great practical importance. When is a person too old to occupy such a critical position in society? This question can be best addressed by looking separately at political, military, religious, and economic leadership.

Politicians When we speak of the relation between age and political achievement, we must recognize that leadership can be assessed many different ways. The most commonly used definition in research is simply to note the age at which individuals are most likely to ascend to a particular political position. At what age do individuals become president, prime minister, senator, governor, member of parliament, secretary of state, ambassador, and so forth? Research shows that the leaders that enter such established political roles tend to have entered their more mature years, most commonly being in their 50s or 60s. Moreover, it is not rare to see status quo political leaders who are even older. At the same time, it is clear that the age distributions tend to vary according to the nature of the political position. Among

politicians in the United States, legislators who serve in the Senate tend to be older than those in the House of Representatives, while among chief executives, those who serve as President tend to be older than those serving as state governors. Of course, some of these contrasts can be attributed to differences mandated by law. Nonetheless, this cannot entirely explain the age differences, because the most typical age ranges tend to be older than those set down by law. For example, most presidents exceed the minimum by about 20 years. In fact, successful presidential candidates tend to be clustered fairly closely around 55 years of age, whereas most losing candidates tend to be either much younger (as young as 36) or much older (as old as 85).

So far we have considered only established political roles. Other political leaders achieve distinction by heading revolts, rebellions, or revolutions against the established government. These revolutionaries and rebels are far more prone to be much younger than their contemporaries who occupy status quo positions. For example, among politicians of the twentieth century it was rare for a status quo politician to attain power before the age of 40. In contrast, almost half of eminent revolutionaries were younger than 35 at the onset of their involvement, and almost 80% were younger than 45. Interestingly, as a political system matures, the average age of its leadership tends to increase as well. This trend is seen in the history of the United States since its inception at the end of the eighteenth century. Members of Congress in the twentieth century are about a decade older than those at the beginning of the nineteenth century. Furthermore, the average ages of those serving as Speaker of the House have increased from the 40s to the 70s. These upward trends cannot be entirely attributed to shifts in mean life span. In fact, for some political positions the trends go in the opposite direction. The governors of the American colonies were actually about 20 years older than the governors of the various states of the union after the revolution. Colonial governors, as subordinates of the British crown, had to more strongly represent the status quo. Hence, the same principle applies. Youth challenges the powers that be, while maturity defends those institutional powers.

These findings all focus on the age at which individuals fill certain leadership roles. Although this is certainly a reasonable criterion of achievement – given the difficulty of attaining these positions – it cannot be our sole criterion. Indeed, a more critical gauge of achievement would be some indicator of the leaders' actual performance during their tenure in office. For example, one investigation looked at the relationship between the age at which a US president is inaugurated and his subsequent performance as an executive, legislator, and diplomat. Absolutely no relationship was found. Older chief executives are no better or worse than those who are much younger, and there exists no peak age for maximum success.

Nevertheless, it is necessary to point out a serious methodological problem with many of these studies. For most political offices in democratic systems, the length of tenure is rather restricted. In the US presidency, for instance, only one chief executive has served more than 8 years, and many have served 4 or less. This is too little time to calculate longitudinal trends. What is required is an analysis of leaders who have served throughout their adult lives. The only political institution for which this is feasible is hereditary monarchy. Because monarchs may then ascend to the throne at a young age and may remain enthroned until death, analyzing these leaders allows us to scrutinize changes in performance over three decades or more. One empirical inquiry that examined a large sample of long-tenured monarchs in fact discovered a tendency for performance to peak around 42 years old. After that peak, there was a gradual decline in the monarchs' ability to expand or maintain their political power and influence. Thus, age decrements can be found when the observations are truly longitudinal in nature.

Military Commanders The study of military leadership presents some of the same problems as seen in the study of politicians. For example, we must be careful to distinguish between the age at which an individual is most likely to occupy the role of general or admiral and the individual's performance in that role. One early investigation, for instance, looked at the age at which commanders led armies in historic battles without noting whether the battle was won or lost. As a result, the information obtained was very limited in its implications. Another difficulty is even more severe than that seen in the study of political leaders: although military careers can last a long time, the central function of those careers, namely, fighting wars, usually has a much shorter duration. It is rare for a major war to last for more than 5 years, and a very large proportion last for only a year or two. Seldom can we trace a commander's tactical success over a long period of time. As a consequence, we often have no other choice but to examine cross-sectional rather than longitudinal data. We must ask whether the age of two opposing commanders in a battle allows us to predict who will be mostly likely to emerge the victor. The answer to this question is affirmative. For instance, one empirical study looked at the winners and losers in 326 land battles. The older a general was in comparison to his opponent,

the less likely he was to take the offensive by attacking first. In other words, older commanders tend to adopt more conservative, defensive tactics. This age trend is important because taking the initiative on the battlefield is a key predictor of tactical victory. In addition, there was evidence of a curvilinear relationship between age and military success. The commanders who were closest to the peak age of 45 years were most likely to be those with the most career victories and the longest winning streaks. Together, these findings suggest that military achievement, at least as defined by battlefield victory, may decline in the later years of a commander's life.

Entrepreneurs Economic leaders are extremely important to the material well-being of any capitalist society. After all, these are the leaders, the businessmen and -women, who market the new products and create the new jobs that are essential to a high standard of living. Yet research on these figures is relatively limited. Most studies indicate that entrepreneurial leadership may peak somewhat late in life. Typically, the most distinguished leaders first reach the high point of their financial power in their late 50s. Moreover, these individuals do not actually attain wide recognition for their economic accomplishments until somewhere in the 60s. Thus, this form of achievement may require more maturity and experience in the business world. At the same time, we must recognize that these age curves are not easy to interpret. The income and influence of entrepreneurs are largely based on decisions made earlier in their careers. The seeds of the wealth of an Andrew Carnegie, John D. Rockefeller, Henry Ford, or other corporate giant were often planted in their 30s. It takes time for the risky investments of youth to make an impact on an industry. Even so, these entrepreneurs usually manage to continue their money-making abilities until quite late in their lives. Only in rapidly changing markets might they find themselves suffering from younger competitors. In this sense, economic leadership is similar to what tends to hold for diplomats and other forms of political leadership in which accumulated expertise is at a premium.

Religious Leaders The life span development of those who lead religious movements and institutions follows a pattern that closely parallels what has been observed for political leaders. On the one hand, some figures attain distinction by becoming the head of some established religious group, whether a church, denomination, or sect. These status quo religious leaders tend to be quite advanced in years. The history of the Roman Catholic papacy provides a typical illustration. Almost all popes were older than 50 years old at the time they were elected, and around two-thirds were well over 65. Furthermore, the optimal age range for becoming pope lies roughly between 80 and 90. On the other hand, the founders of new world faiths are often much younger. It is extremely rare for a founder to be older than 60. Most tend to be between 35 and 38, and many are much younger than that optimum interval. For example, from the history of Christianity, John Wesley founded Methodism at age 35, Martin Luther launched the Protestant movement at 34, Ignatius Loyola wrote the 'Spiritual Exercises' at 30, John Calvin wrote the *Institutes* at 27, Joseph Smith begun Mormonism at 25, and George Fox founded the Quaker faith at 23. Jesus himself was probably around the age of 30 at the height of his mission. Similar statistics hold outside the Christian faith. For example, Buddha was probably in his mid-30s when he began teaching the fruits of his enlightenment. Of all the world's major faiths, Islam had the oldest founder, and even he, Mohammed, was only 40 when he became the Prophet. Facts such as these support the conclusion made by G. Stanley Hall that "men in their prime conceived the great religions, the old made them prevail" (Hall GS (1922) *Senescence: The Last Half of Life*, p. 420. New York Appleton). Curiously, when exceptions to this rule seem to appear, the underlying principle persists upon closer examination. Thus, Popes Innocent III and Leo X, for instance, entered the pontificate in their late 30s. Yet both were extreme activists, the former in the political sphere and the latter in the cultural.

Creativity

The subject of the relationship between age and creative productivity has already been treated at length in the article on creativity in this encyclopedia. Therefore, here we need only to summarize the six central findings.

Typical Age Curve When we plot the number of contributions individuals make as a function of their age, we discover a single-peaked, inverted-U curve. More specifically, the output of works first increases up to a certain optimum, after which productivity gradually declines. By the 80th year of life, output is about 50% of the level reached at the career peak. Although this might seem a substantial drop, we must note two extenuating facts. First, even a creator who is well advanced in years can expect to maintain a respectable level of creative productivity. Second, the output rate seen by individuals in their 70s is about the same as that seen by those in their 20s.

In this sense, septuagenarians can hold their own against the youngest members of their discipline.

Interdisciplinary Differences The typical age curve varies substantially according to the specific domain of creative achievement. In some fields, the peaks may appear relatively early in life, and the post-peak declines can be relatively rapid. This is the situation for lyric poetry and abstract mathematics, for example. In other fields, however, the productive optima usually occur much later in life, even as late as the 50s. Such delayed peaks are common in history and philosophy. Furthermore, those creative domains that feature later productive maxima also tend to exhibit gradual, even negligible, declines. Thus, in these late- and slowly maturing disciplines, aging has minimal impact on creative achievement. Moreover, even in those disciplines characterized by early peaks and rapid declines we do not expect the output rate to drop to zero. In fact, the typical creator in these domains will maintain a level of productivity by age 80 that will equal about 10% of that observed at the career peak.

Career Versus Chronological Age Although most researchers have tended to view the longitudinal changes in terms of chronological age, this practice is not really correct. Instead, the curves expressing changes in creative productivity are better defined according to career or professional age. Those who begin their careers earlier in life will tend to exhibit earlier peaks as well. By the same token, those whose careers get a very late start will normally enjoy later peaks. This means that it sometimes happens that late bloomers will actually attain their career high points in the last one or two decades of life. In addition, it is perfectly possible for a person to exhibit two career peaks. This can happen when an individual already successful in one field decides to make a mid-life career change and thus develops a second successful career in later life.

Individual Differences We should not overlook the fact that individual differences in creative achievement are quite substantial. Not all creators are created equal; rather, some produce considerably more creative ideas than their less-accomplished colleagues. In most disciplines, the top 10% who are the most productive are usually responsible for 50% of all contributions in the field, whereas the bottom 50% who are the least productive account for only about 15% of the total achievement. This cross- sectional variation explains more variance in output than the longitudinal changes attributed to career age. Accordingly, highly prolific creators who are in their 70s or 80s will equal or even exceed the output levels of other, less productive creators who are in their 30s or 40s.

Equal-odds Rule There are two ways we can count output across the career. On the one hand, we can simply tabulate the total number of works produced, regardless of whether the pieces are successful or not. For example, we might count the number of scientific papers produced per decade without regard for whether these papers made any contribution to the field. On the other hand, we might restrict our counts to merely those creations that can be considered genuine achievements. For instance, we could tabulate those scientific papers that receive a specified number of citations in the publications of other scientists working in the same discipline. The first kind of measure gauges quantity, or pure productivity, while the second kind of measure assesses quality, or real creativity. Obviously, if our standpoint is one of achievement, the exclusive quality measures are superior to the inclusive quantity measures. This distinction also has interesting repercussions for understanding how aging affects creative achievement. In the first place, the age curves for quantity and quality are essentially the same. Those periods in an individual's life in which the most works are produced are also those in which the most influential products are most likely to emerge. Furthermore, if we calculate the proportion of successful works to total output, we find that this quality ratio fluctuates more or less randomly throughout the career. This means that older members of a creative enterprise will have roughly the same success rate as those members at their supposed creative prime. In other words, even though the elder creators may be producing fewer masterpieces, they are also generating fewer neglected works. This equal-odds rule suggests that from the perspective of the quality ratio, we cannot realistically speak of an age decrement at all. Age is simply unrelated to the probability of success.

Last-works Effects We can advance a step beyond the last point. Highly creative individuals will frequently undergo a resurgence of creative activity toward the end of life. This upsurge in total output, as the equal-odds rule maintains, will correspond to an increased production of important works. More importantly, as death draws near, the creativity of these individuals will often undergo a qualitative transformation that renders their final works quite distinct. In the visual arts, for example, it is not uncommon for master painters to enter into a phase in which their works exhibit a notable 'late style.'

In addition, creators will often devote considerable effort to the production of a single piece that successfully serves as an artistic last testament or career capstone. In classical music, for instance, this creative shift has been called the swan song phenomenon. What makes these achievements especially significant is that they often appear when the individual's health has been undergoing chronic and debilitating deterioration, such as blindness, deafness, arthritis, and other infirmities. Thus, the age curves notwithstanding, the aging process need not prevent exceptional creators from maintaining their creative powers right to the end.

Entertainment

In this final category are placed several miscellaneous forms of achievement that cannot be classified as either leadership or creativity. Because the number of potential domains is extremely diverse, we review only three representative areas of accomplishment, sports, chess, and film.

Athletes Among all the principal domains of achievement, accomplishments in sports are almost exclusively the province of youth. Sports championships, such as the Olympics, are predominantly populated by athletes in their 20s. Indeed, for some events, like swimming, it is the teenagers who are most likely to prevail. Moreover, the various age optima for athletic competitions tend to be quite stable over long periods of time. For instance, the mean age of Olympic gold medalists in track and field events has stayed relatively constant since the first Olympics were held. In addition, the variation around these means is usually rather small. For most athletic activities, the top athletes will be no more than 5 years apart in their ages.

On the other hand, it is also true that the ages of peak achievement tend to vary systematically according to the particular sport. In swimming and track, for example, there appears a fairly consistent tendency for the longer events to be won by older athletes, the differences sometimes exceeding 5 years. More importantly, the age optima are even greater for those competing in sports in which skill is more important than speed, strength, or stamina. Thus, champions in shooting, golfing, bowling, and billiards are most frequently in their early 30s. Even so, there exists no regular sport in which the championships are most commonly held by athletes in their 40s or older. So, the main generalization stands: older adults cannot be expected to compete at the same level as younger athletes.

However, this last remark should not blind us to another fundamental truth. There always exist substantial individual differences in athletic performance, differences that tend to be relatively stable across time. Consequently, a top athlete past his or her prime may still be competitive with lesser athletes who are at their prime. Whenever we focus on those who receive the gold medals or most valuable player awards, we tend to forget that there are older competitors that came in third or fourth in the event, match, or ballot. One classic illustration is the baseball pitcher Nolan Ryan, who went from a record-breaking player in his late 20s to a still highly competitive player in his late 30s. In fact, he was still breaking records shortly before injury forced his long-delayed retirement.

Chess Masters In the previous section we observed that those sports that place the most emphasis on skill are most likely to be those with older champions. This tendency may lead us to ask: what about those competitive activities in which the skill is entirely mental rather than physical? For example, because card and board games do not require any extraordinary proficiency in eye–hand coordination, we might anticipate that the premiere players who win championships can do so at older ages than is typical in sports. There is indeed evidence that this expectation fits the facts. For instance, Arpad Elo devised an objective measure of the performance of chess masters, which he then used to gauge how expected performance changed over the career course. The average age for peak competitiveness was around 36, and the range of maximal to near-maximal performance was between the late 20s and the late 40s. Furthermore, a player at about age 63 could expect to play as well as a player at around age 21. Hence, the assets of youth are much less conspicuous for a competitive activity that is almost entirely intellectual in nature.

Finally, what was said of athletes holds equally well for chess grandmasters. The strongest players in the later stages of their careers are superior to lesser players in their prime. Individual differences in skill are so pronounced as to often overwhelm longitudinal changes in competitive ability. A prime example is a player like Emanuel Lasker, who became world champion in 1894 and successfully defended his title when he was 53 years old. Significantly, even in his 60s Lasker was able to pull off some classic victories in chess competition.

Movie Stars The final domain of achievement in entertainment concerns actors and actresses in film. Acting may seem far removed from the preceding

two domains, yet in certain respects they are actually comparable. In the first place, the movie business is extremely competitive, so that only a small percentage of aspiring actors and actresses can expect to attain star status. Second, like chess, acting largely represents an intellectual skill that is acquired and developed. Third, like athletics, success in films requires certain physical attributes, even if these characteristics are not usually of the same kind demanded in sports. In particular, it is rare for an actor or actress to rise to stardom without emanating an unusual amount of physical attractiveness. Whether we call them handsome or beautiful, most project in their performances a certain amount of sex appeal. This latter attribute raises an intriguing question: might not the relation between age and achievement within this domain vary according to gender? After all, the sexual attractiveness of men and women may change in different ways as a function of the aging process. Indeed, whereas women might quickly lose sex appeal, men might actually gain as their appearance grows more masculine and distinguished. Only if the skill component of great acting predominated would we expect the accomplishments of actresses and actors to follow the same life course.

Research on this question supports the conclusion that gender contrasts are in fact quite conspicuous. For example, one inquiry looked at the ages of the actors and actresses who were the top money makers. The curves for the two sexes were dramatically different. The women began to make big money earlier, around their late teens, reached the peak of their careers in their late 20s, and were largely finished as box office attractions by their late 30s. The men, in contrast, did not really take off until their early 20s, attained their peaks in their early 30s, and, most significantly, continued to enjoy some box office success until they attained their late 60s. Curiously, largely the same age curves appeared for stars who turned in best performances, as judged by movie critics. The best performance of an actress most often appears in her late 20s, that of an actor in his early 30s. Furthermore, whereas the women have little chance of such an accomplishment beyond age 40, the prospects for actors remain good into their 60s. Hence, physical attractiveness may be far more crucial than performance skill in determining the achievements of movie stars. Not only must women be younger than men to maximize success, but also women experience a more precipitous drop in their opportunities for stardom. Admittedly, these curves represent only statistical averages, and accordingly exceptions do exist. Katherine Hepburn is a classic illustration of a woman whose achievements as an actress survived the deterioration of her physical beauty. Nonetheless, for the vast majority of movie stars, the aging process harms the careers of women much more than those of the men.

Theoretical Explanations

The previous section emphasized the empirical findings on the connection between age and achievement. No attempt was made to discuss the theoretical explanations for these diverse results. In this section, this deficiency is rectified. The available substantive interpretations may be grouped into three categories: biological, psychological, and sociological.

Biological Processes

It is perhaps too common to explain any age decrements in achievement in terms of the adverse effects of the aging process on individual health. Older persons almost invariably experience marked declines in physical vigor. Aging also brings about a slowing down of mental functioning due to changes in the central nervous system. In addition, it may take increasingly longer to overcome the disabilities resulting from injuries and infections. No doubt these biological consequences of aging take their toll on an individual's capacity for achievement. Yet these interpretations are incomplete. For example, a purely biological explanation cannot account for why career age is more predictive of creative productivity than chronological age. Those who get a late start on their careers may actually be attaining their career peaks when they are well advanced in years. Nor can the physical repercussions of aging help us understand the basis for interdisciplinary contrasts in creative output. It takes far more physical exertion to write a novel than to write poetry, and yet novelists peak much later in life than do poets. In all, we must realize that biological interpretations have to be applied with extreme caution. Otherwise, we may overlook the fine details regarding the relation between aging and achievement.

Nonetheless, in some domains biological processes can carry most of the explanatory weight. This is most evident in sports. As pointed out, the optimal ages for top performance in various athletic competitions have remained rather stable for at least a century. The age at which an individual is most likely to become an Olympic champion depends almost entirely on the nature of the athletic event and the gender of the participant. All the medical advances of the twentieth century have not significantly modified these age curves. This temporal stability suggests that there are fundamental physiological bases for the age curves. Sprinters will be younger than long-distance runners for purely physical reasons.

Biological explanations may take another form as well. According to sociobiologists, some patterns of human interaction are the products of standard evolutionary processes. Since the beginning of our species, individuals have been engaged in the business of optimizing their reproductive success, and this preoccupation has favored the dominance of certain types of social behaviors. For example, if individuals select mates according to fertility, then the attractiveness of men and women should exhibit very different age curves. Whereas women are maximally fertile in their 20s and early 30s, men maintain their fertility until much later in life. This contrast may help explain the dramatic difference between the career trajectories of actors and actresses. Because a woman's fertility declines so precipitously, her sex appeal on the silver screen suffers a drastic drop as well, until the actress is no longer seen as a box office attraction.

Of course, this sociobiological principle alone cannot explain why actors get a slower start than actresses. After all, young men can prove to be quite fertile. However, here we can evoke another explanatory principle from sociobiological theory, namely, that the sexual attractiveness of men is influenced by their success in life's competition. Attractive males are supposedly survivors who have endured the tests and have emerged victorious, as evinced by their control over power and resources. By this account, then, an older male holds the edge over the younger male. This would explain not only why actors peak later than actresses, but also why the decline is so much more gradual. Men in their 60s can display an attractiveness only enjoyed by women in their 20s. Incidentally, this same phenomenon may also account for why status quo political and religious leaders tend to be older. Social animals increase their reproductive success by selecting the best individuals to lead their group. These are going to be the individuals with the most experience and success. As a consequence, whereas successful actresses tend to be much younger than successful actors, women leaders tend to rise to power at about the same age as men.

Considerably more research must be undertaken before we can have full confidence in sociobiological explanations. Even so, these accounts indicate that the impact of biological processes can be far more subtle and complex than simply attributing achievement decrements to the infirmities of age.

Psychological Processes

Many have proposed that the linkage between aging and achievement reflects more fundamental changes in the psychological processes that underlie the attainment and maintenance of success. Perhaps the single most common explanation is cast in terms of a possible age decrement in intellectual functioning in the later years of life. Particularly provocative is the distinction between two varieties of intelligence, namely, crystallized and fluid. Crystallized intelligence concerns knowledge, information, and expertise, whereas fluid intelligence concerns flexible problem-solving ability. Whereas the first may increase or at least stay relatively constant across the life span, the second may exhibit fairly sharp declines in the later years of life. This contrast in developmental trends may help us understand the interfield differences in career trajectories, because each domain of achievement probably requires a different optimal mix of crystallized and fluid intelligences. For instance, diplomats, historians, or heads of established churches probably need more crystallized than fluid intelligence, and thus their career peaks appear in advanced maturity. On the other hand, revolutionaries, poets, and founders of new faiths may need more fluid than crystallized intelligence, thereby pushing the career optima toward more youthful ages.

However, we must acknowledge that motivational factors may also play a role, perhaps even the most important role. For example, one investigator has proposed that achievement is a function of two components: experience and enthusiasm. While experience continuously increases with age, according to this theory, enthusiasm first increases up to a peak sometime in the early 30s and thereafter decreases. The career optimum then appears where the sum of these two curves maximizes, which occurs around the late 30s. Yet different domains may require a characteristic mix of experience and enthusiasm. Revolution and poetry, for instance, may require greater zeal, whereas diplomacy and history may demand more wisdom. The career peaks will appear at different ages accordingly.

The foregoing explanations operated under some kind of age-decrement assumption. Either intellectual ability or enthusiasm underwent an age-related decline in the processes that underlie achievement. Nonetheless, other psychological explanations do not presume the occurrence of such inexorable age decrements. For example, some researchers have proposed psychoeconomic theories that presume that achievement operates in a manner similar to business investment. Achieving individuals are trying to optimize their long-term assets, and to do so they must invest in their human capital. The utility of these investments may diminish in the latter part of any life for the simple reason that an individual is less likely

to be around to reap the profits. Nonetheless, this choice to redirect effort may be reversed if at any time the person perceives an altered cost–benefit ratio. Such calculations may result from modified family circumstances, career changes, and more optimistic perceptions of probable life spans. The important point here is that the achievement potential of individuals may not necessarily decline just because the observed levels of achievement may appear to fall off. At different stages of their lives, people must adjust their priorities according to considerations that are unrelated to inherent capabilities.

Sociological Processes

We must not ignore the often extremely powerful impact of larger societal forces on the relationship between age and achievement. Sometimes these influences may take a rather explicit form. Political institutions, in particular, will often possess constitutions or by-laws that specify the acceptable ages at which certain positions of authority may be occupied. The US Constitution, for instance, states that an individual must be at least 25 to serve as a member of the House of Representatives, 30 to serve as Senator, and 35 to serve as President of the United States. This means that the age curves are automatically truncated at the lower end and that the occupants of the various federal positions will exhibit a certain amount of age stratification. Although other political systems have been successfully governed by very young heads of state, such a possibility is constitutionally prohibited in the US system. Of course, the legal restrictions can just as well go in the other direction. For many years, and in many places, organizations both private and public practiced mandatory retirement. We will never know how many potential achievements never saw the light of day because individuals at age 65 suddenly found themselves denied the resources to continue their work.

These institutional constraints cannot tell the whole story, however. Other social realities have a part to play as well. The US presidency provides another illustration. Why is it that successful presidential candidates tend to be in their mid-50s, whereas unsuccessful candidates tend to be either younger or older? One could argue that this age function reflects a fundamental necessity of presidential politics. In order to get elected to the White House, one must build a political base, a foundation that relies most heavily on a candidate's own cohort. Those who are much younger than 50 probably have not yet managed to construct the necessary broad support. Furthermore, those who are much older than 50 will likely see their political base erode as members of their cohort retire or die and as younger politicians recruit support from the younger generations. Hence, the career trajectory here may represent nothing more than the pragmatics of coalition formation. A candidate's intrinsic capacity for leadership may have relatively little impact on this process.

Although these examples all focus on leadership, social influences may determine the career trajectories for other forms of achievement as well. For instance, the optimal age for creativity in scientific disciplines tends to increase as a discipline matures. It takes more time for individuals to acquire the necessary expertise, and it requires more time to work out the implications of any given idea. Moreover, we have by no means discussed all the sociological processes that affect the location of the age peak and the magnitude of the post-peak decline. It should suffice to say that the amount of achievement that we can legitimately expect of older achievers is a complex function of biological, psychological, and sociological factors. Under the right combination of these factors, the amount of achievement that we can anticipate from even octogenarians is truly substantial.

See also: Creativity; Decision Making and Everyday Problem Solving; Learning; Productivity and Age; Work and Employment: Individual.

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Adaptation

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Glossary

Adaptation – The ability to maintain a consistent view of the self over time, facilitated by the use of coping strategies, that enhance the individual's emotional state and present the individual with viable ways of making practical changes that compensate for losses in physical and mental functioning.

Competence Adaptation Model – A model in which optimal adaptation is theorized to occur when the individual's functional abilities are matched to the degree of stimulation and challenge presented in the environment.

Defense Mechanisms – Emotion-regulating strategies through which individuals attempt to minimize feelings of anxiety.

Identity Process Theory (IPT) – Theory that conceptualizes identity as a biopsychosocial entity that encompasses the individual's self-representations and experiences encountered in the realms of physical, psychological, and social functioning.

Introduction

The search for the key to satisfactory adjustment in old age is the basis of a significant body of work within the fields of psychological and social gerontology. Some of the earliest research on personality and social development in later life addressed the enormously complex issue of trying to identify the 'best' or most 'successful' way for the individual to age. These empirical attempts involved the description of different personality types who varied in their approach to the aging process, from 'disengaged' to 'active.' Whether it was beneficial for the older individual to take a passive or an active approach to the aging process served as the touchstone for considerable controversy and debate among gerontologists. A now-discredited view of psychological aging, 'disengagement theory,' proposed that older adults become increasingly oriented toward internal preoccupations as they face the inevitability of death, and that this movement inward was psychologically adaptive. Despite the theory's lack of support, there still persisted the idea in the gerontological literature that with age, individuals become more preoccupied with their own psychological concerns and less oriented toward other people.

The notion of a radical alteration in personality in response to the aging process is not substantiated by research. Instead, it is becoming recognized that the challenges presented to the individual's personality by the aging process are adapted to according to that individual's personality. Successful adaptation to the aging process is seen, in these terms, as involving the ability to maintain a consistent view of the self over time. In addition, the individual must adjust to the normal physical changes brought about by aging: increases in chronic health problems, alterations in social and community roles, and, ultimately, the proximity of death. These adjustments are facilitated by the use of coping strategies that enhance the individual's emotional state and present the individual with viable ways of making practical changes that can compensate for any losses in physical and mental functioning.

Contemporary researchers are directing their efforts, on the one hand, to this search for the optimal path of adaptation to the demands and challenges presented by the aging process and, on the other hand, to the factors that increase the risk of depressive reactions in later life. It is recognized that adaptation in later adulthood reflects a biopsychosocial process reflecting the multidimensional influences of biological, psychological, and social forces that have operated throughout the individual's life course.

Coping and Adaptation in Later Adulthood

The adaptational demands presented to the older individual can be seen as challenges to the individual's ability to cope. Cognitive models of coping define stress as the perception of threat. In later life, such threats can come from events related to bereavement, poor health, caregiving, fears of aging, risks to personal safety, threats to self-esteem, and uncertainty of life beyond death. Often, these threats are of a chronic nature. Coping, in turn, can take one of two forms. In emotion-focused coping, individuals alter their perceptions of a stressful situation; in problem-focused coping, by contrast, individuals take actions designed to change the situation itself. Passive, emotion-focused coping strategies appear to characterize the reactions of elders who are less successful in managing stress. These strategies include self-blame, wishful thinking, avoidance, fantasy, and escape into

drugs and alcohol. Unfortunately, people tend to attribute mild, short-term symptoms to aging, leading them to adopt more passive coping strategies, and it is these strategies that ultimately can reduce health status even further.

By contrast, successful elders use active, problem-focused coping strategies, including sport and physical recreation, interacting with others for social support, and keeping busy by participating in social groups and learning new skills. Successful copers see themselves as being in control of their experiences, view themselves positively, and take a confrontive, optimistic, and self-reliant approach to stressors. In cases of chronic illness, they accept restrictions, but still look for new possibilities in life. An active, problem-focused coping style seems, then, to be positively associated with handling adversity in later life. However, this style of coping does not necessarily involve close self-scrutiny, introspection, or an intensive process of life review. A positive orientation to one's past life based on involvement with family and a focus on past successes may help the older adult view the future more positively. For some individuals, prayer may prove beneficial as a coping strategy that allows them to feel in control of, for example, health-related stresses.

Defense mechanisms, emotion-regulating strategies through which individuals attempt to minimize feelings of anxiety, are closely related to coping in that they help the individual manage stress. Age differences in defense mechanisms and related coping processes were the focus of two major cross-sectional investigations. In general, older adults were better able to manage their emotions through the use of what were considered the 'mature' defense mechanisms of controlling negative emotions or trying to put the situation into perspective. Similarly, in their coping strategies, older adults showed less of a tendency than younger adults to react in self-destructive or emotional ways. Aging individuals were more likely to attempt to understand the situation and figure out a way around it, through both problem-focused coping and use of other strategies such as suppressing their negative feelings or channeling those feelings into productive activities. Younger people, including adolescents and young adults, were more likely to react to psychologically demanding situations by acting out against others, projecting their anger onto others, or regressing to more primitive forms of behavior. Consistent with these findings, a longitudinal study of over 2800 adults studied from 1971 to 1994 revealed that aging was associated with a decrease in negative affect.

Consistent gender differences have also emerged in studies of defense mechanisms and coping. Regardless of age, women are more likely to avoid unpleasant or stressful situations, to blame themselves when things go wrong, and to seek the support of others. Men are more likely to externalize their feelings and to use reaction formation.

There are significant ethnic and cultural variations in coping strategies. Those older African Americans who have had a lifetime of rehearsal in using social support during times of stress and developing flexible ways to seek help are in some ways better prepared to cope with stress. Furthermore, while people in many ethnic groups may experience a lifetime of poverty and adversity African Americans who do so may be better able to handle uncertainty. However, they may face additional demands that tax their adaptational resources, for example, when they become caregivers to their grandchildren. Although they may have strong support networks, they are economically overwhelmed when they must take on this role, as the majority of them live below the poverty level. Nevertheless, African American caregivers as a group, despite the economic and physical strains they experience, have lower levels of depression and caregiver burden than White caregivers. In contrast, Hispanic and Asian American caregivers report higher levels of depression than Whites. Apart from their reported emotional states, all racial and ethnic minority caregivers are in poorer physical health than their White counterparts, indicating that lack of resources and feelings of filial obligation ultimately take a higher toll.

Another strategy for adapting to stress involves the process of social comparison, a mechanism that can be used to assess one's position in terms of the stereotypes regarding age-related changes. Older individuals may use social comparison to help negotiate potentially stressful transitions, such as having to relocate their place of residence. In this sense, the stereotypical view of the changes that come with aging can serve to function in the adaptation process. This view of aging can provide a set of 'normative' experiences and losses to which individuals can compare and accept their own experiences. Also, such stereotyped views of aging provide a buffer that can protect one's sense of well-being because one's actual experiences will, by comparison, appear more successful and adaptive. The result of social comparison is that older adults are able to maintain or even expand their degree of life satisfaction even as they experience real age-related changes in functioning.

Religion also plays a role in adapting to difficult life circumstances, serving as another important coping resource for many older adults. Through involvement in community religious activities, the individual can access important social network resources as well as

receive verification of his or her role as contributing members of society. Belief in the values and teaching of one's religion can also provide the individual with a source of inner strength and sense of purpose in life. The sense of burden that elders may feel in attempting to cope with their own health problems or those of family members can be alleviated when viewing these demands in terms of fulfilling a higher purpose in life.

It appears that successful agers find ways to adapt their coping strategies to reduce the stressors they encounter in their daily lives. They also take advantage of the principle 'use it or lose it,' by finding ways to compensate for physical and psychological changes associated with the normal aging process that can potentially interfere with the ability to perform daily activities and to cope successfully with environmental stressors. These compensatory activities may include regular and consistent involvement in physical exercise, the seeking of intellectual stimulation, and the willingness to take advantage of commercially available prostheses such as proper hearing aids and eyeglasses. Going beyond the concept of coping, which implies a responsiveness to externally produced events, some elders seek new levels of personal growth and development through constant searching for new opportunities to learn and stay involved in the world around them. Furthermore, elderly adults with a lifetime of experiences with stress have developed unique strengths to aid them in this coping with the aging process.

Adaptation to the Environment

The quality of the physical and social environment must also be considered in understanding adaptation to changes associated with later life. Theoretical models relating the individual's adaptation to the quality of the environment point to the need for a match or 'fit' between the characteristics of the individual and the demands of the environment. Perhaps the most well-known of these approaches to person–environment interaction is the competence adaptation model. In this model, optimal adaptation is theorized to occur when the individual's functional abilities are matched to the degree of stimulation and challenge presented in the environment. Another aspect of person–environment fit involves the matching of the individual's motives and needs with the 'press' of the environment. An individual with a high need for autonomy, according to this model, would be optimally adjusted in an environment that promotes and supports the independence of the individual. If that environment fosters dependence, the individual's adaptive ability will be reduced. In other words, using one's personal resources proactively will result in greater well-being than passively reacting to the demands of the environment. This dynamic interplay influences adaptation on the emotional or physical level. Furthermore, without stimulation or reinforcement for independent, autonomous behavior, it is likely that the individual will enter a downward spiral of accelerated deterioration and dependence.

Adaptation to Physical and Cognitive Changes

Physical and cognitive changes associated with aging place demands on the individual's ability to adapt to the environment. When age-related changes create difficulties in physical mobility, social interaction, and everyday decision making, the individual's quality of adaptation to the environment is compromised. This reduced adaptive ability creates more problems in daily life, as the individual finds it more difficult to go about his or her daily routine. Equally important is the effect of the individual's lowered adaptability on feelings of competence. Psychologists have long argued that feelings of competence play a major role in self-concept and identity. If the aging individual is and feels less able to handle daily tasks, he or she will begin to suffer losses in sense of self-esteem and feelings of self-efficacy. Furthermore, this loss of competence invades the individual's sense of stability and continuity over time, as the individual is forced to redefine the self as less capable than in earlier years. The overlay of negative social attitudes toward the aging process further contributes to the potential erosion of the individual's identity as a competent and worthwhile individual. All of these changes may be reflected in a variety of psychological symptoms and a further reduction of competence, as the individual begins to live out a fatalistic self-fulfilling prophecy in which he or she simply gives in to the inevitability of the aging process.

Countering the downward spiral is the natural spirit that many elders have as they approach the aging process, in which they regard the changes with age as a challenge not unlike the many others they have faced in their long lives. Rather than become demoralized by the awareness of a progressive deficit in functioning, they seek ways to reverse or at least slow down this manifestation of the aging process and spontaneously compensate for loss of functioning in one area by building strengths in others. Although these behaviors promote their adaptation to the environment and maintain their sense of identity and self-efficacy, individuals who take this active approach to the aging process run the risk of becoming demoralized and frustrated when they are faced with changes that they cannot overcome. They are

particularly vulnerable to rapid-onset diseases that negate their prior efforts to remain healthy and active.

Adaptation to Changes in Social Roles

In western society, great value is placed on the individual's economic productivity, which traditionally is linked to worth. Due to the social and cultural emphasis on economic worth, retirement presents the potential for an individual to feel devalued and stripped of social importance. Furthermore, given the assumption that autonomy and independence are desirable qualities, the reliance of older individuals on the government or private pension plans for subsistence can challenge their sense of well-being as contributors to society. Added to these difficulties are views of the older generation as a financial drain. The news media's coverage of the national debt portrays elders as a drain on the budget due to the vast funding needs of Medicare and Social Security. Discussion of the health-care needs of the aging population often focuses on dilemmas regarding prolonged treatments of terminally ill patients on life support. As health-care costs skyrocket, older adults are seen as presenting even more of a threat to overtaxed public and private health-care insurance companies. These negative attitudes can affect not only people's expectations about the process of aging, but also the self-perception and affective experiences of the older people who are at the heart of these frightening scenarios.

Individuals may be expected to vary, however, in the extent to which they incorporate society's negative views about aging and older adults into their identities and sense of well-being, particularly with regard to the economic and psychological transitions to retirement. For older adults socialized in the importance of the work ethic, loss of their occupation through retirement can be a major blow to their sense of well-being. They may feel useless and regard their lives as devoid of meaning. Other individuals, however, may be able to draw upon their previous identities within the world of work, defining themselves as retired 'Xs,' where 'X' represents the individual's primary past occupation. Development of involvement in leisure and recreational activities prior to retirement may also moderate the individual's response to retirement. An individual who maintains an active lifestyle can adjust more readily to the disappearance of work from daily routines than an individual whose work completely determined the activities of his or her daily life.

Changes within the context of the family represent another challenge to adaptation for the aging individual. Married couples experience a number of changes associated with the aging process that can pose significant threats to the later-life relationship and, ultimately, each individual's sense of well-being. The task of caring for a married elder who becomes infirmed due to physical changes or Alzheimer's disease typically falls to the spouse, and can be a source of unending stress and burden. Another set of challenges pertains to the area of sexuality. There are many common stereotypes and misconceptions regarding the potential for enjoyment in the later years. Older couples can sometimes be affected by these negative, and usually inaccurate, beliefs. For example, some individuals might think that it is abnormal, or even morally wrong, to maintain an active sexual life into their later years. But for most couples, sexual intimacy does remain an important component of the relationship over the years of marriage. Even if this intimacy does not consist of sexual intercourse, the expression of affection and loyalty can become very important in the later years. It is worth noting that although older couples still view sexual intimacy as important, they also place a greater value on qualities that develop over time, such as security and level of commitment to each other.

The exit from and reentry to the home by grown children is increasingly becoming an adaptational challenge due to economic changes affecting the job options for young adults. Changes caused by the movement of children into and out of the home affect not only the physical space and privacy of the older couple, but also their intimate relationships. The return of adult children can require the older couple to reestablish interaction patterns within the household that are more characteristic of their middle adult years, leading to an exacerbation of potential stresses existing at that time.

Traditionally, households had only one person who retired from the workplace, but here again, patterns are changing so that there are increasing numbers of households in which both partners are employed. In this case, the couple may chose to retire at different times or plan their retirement together. Choosing to retire in an unsynchronized fashion can have a major impact on intimacy due to the fact that each partner in the relationship faces role changes at different times, making the adjustment to a new lifestyle as a couple potentially more challenging. After retirement, the daily lives of both members in the relationship change drastically. Time once occupied by the requirements of work no longer presents a restriction, and other activities must be found to take its place. As a result of this transition, couples find that they are able to spend a considerably greater amount of time on the growth of their relationship,

perhaps narrowing their interactions increasingly to each other and a few close friends. This increased time together may have favorable effects. Couples who remain together can become more accepting, tolerant, and respectful of their partners, and behave in ways that are more affectionate and loving. The increase in free time may lead some couples to spend some of that time interacting with friends, an activity that can bolster marital satisfaction through strengthening the partners' identity as a couple.

There can be benefits, then, as well as challenges, as the married couple ages. Personal differences, which for many years may have been held in abeyance due to the competing demands of children and work, often come back into focus at this time. In learning to interact as a dyad once again, the couple is often faced with the challenge of developing new ways to communicate and make decisions. By identifying and working out solutions to marital difficulties, the couple can often maintain a satisfying relationship as well as develop an even greater level of enjoyment from the partnership. This is an especially challenging task in the postretirement years, because the couple will be not only working on their relationship together, but also learning to restructure their own personal time.

The Role of Identity

The process of adaptation may also be seen as involving psychosocial factors relating to the quality of the individual's investment in relationships, understanding of one's place in the life course, and resolution of issues related to mortality. These factors are best understood in the context of Erikson's (1963) eight-stage psychosocial model of the life cycle, in which it is assumed that change occurs systematically throughout the years of adulthood. Erikson proposed that after adolescence, with its often tumultuous search for identity, adults pass through three psychosocial crisis stages. The stages corresponding to the early and middle adult years focus on the establishment of close interpersonal relationships (intimacy vs. isolation) and the passing on to the future of one's creative products (generativity vs. stagnation). In the final stage (ego integrity vs. despair), the individual must resolve conflicted feelings about the past, adapt to the changes associated with the aging process, and come to grips with the inevitability of death. Erikson's ideas, although difficult to operationalize, have provided a major intellectual inspiration to workers in the field of personality development in adulthood and old age.

In Erikson's model, each psychosocial crisis is theorized to offer an opportunity for the development of a new function or facet of the ego. However, the crisis involving identity has special significance, as it establishes the most important functions of the ego: self-definition and self-awareness. Following the development of identity, according to Erikson, additional functions of the ego, including love, care, and wisdom, can evolve. In old age, according to Erikson, the individual engages in a process of reviewing past experiences and incorporating those into a cohesive and positive identity. The sense of identity that emerges from this process, which Erikson called 'existential' identity, plays an important role in adaptation to the changes experienced in later life and the ability to meet death without fear. For some elders, this process might involve a reassessment of past goals and expectations to meet future needs; for others, it might mean taking the time to examine their sense of self and to conform their identity to the life that they have actually lived.

Models of coping tend to focus on ways in which individuals appraise and attempt to reduce stress by adopting particular interpretations of themselves in relation to threat. However, traditional models of coping do not incorporate the notion of the self in the sense of examining how individuals interpret events as reflections of or challenges to their sense of identity. This failure to address the role of identity ignores an important component of the stress–environment appraisal equation in two important ways. First, successful coping can be seen as a self-enhancing process that can improve the individual's well-being. Second, many events are appraised as stressful if they challenge the individual's self-conceptions or are seen as threats because the individual believes that he or she lacks important coping skills. Older adults may find even a seemingly innocuous event, such as a friendly bridge game, highly stressful if they feel that their ability to count the cards that have been played has suddenly vanished.

Adding identity to the stress and coping formulation brings in this crucial dimension. Erikson's framework provides a starting place for examining identity in adulthood, but it stops short of postulating how identity may continuously develop throughout a life of experiences that can lead to the growth and differentiation of the individual's basic sense of self. Identity process theory (IPT) conceptualizes identity as a biopsychosocial entity that encompasses the individual's self-representations and experiences encountered in the realms of physical, psychological, and social functioning. Using IPT, we can expand and deepen our understanding of adaptation throughout the years of adulthood.

As a biopsychosocial entity, identity includes multiple dimensions of self-schemas. These are physical

(able to lift a heavy weight), cognitive (able to remember a telephone number), and social (holding valued roles in the community). The majority of individuals tend to have positive self-schemas in which they view themselves as competent, effective, and important to others in their social network.

IPT proposes that individual development in adulthood can be best understood according to the relative use of three identity processes: identity assimilation, identity accommodation, and identity balance. Although individuals rely on all three sets of processes, they do so to differing degrees. Identity assimilation refers to the interpretation of identity salient experiences in terms of previously established schemas that include thoughts and feelings about the self. When individuals use identity assimilation, they tend to minimize the impact of age-related experiences that might challenge their self-schemas as able and competent, such as forgetting an important fact or a relative's birthday.

Because identity assimilation serves to protect the individual from potentially negative feedback about the self, it helps to bolster the individual's well-being. Unfortunately, there may be risks involved in using identity assimilation to the point where protection becomes denial of potentially important information about the self. For example, by using identity assimilation to an undue degree, an older adult with arthritis may injure an already ailing joint by overexertion.

In contrast to the minimization of potentially negative information associated with identity assimilation is the process of identity accommodation, which involves changes in identity in response to new experiences. On the positive side, the individual does not suffer from the denials and distortions that can lead to negative consequences in people who use identity assimilation. In terms of adaptation, it is identity accommodation that accounts for making necessary changes in the self in response to experiences that demand change. The cost of identity accommodation, however, is the tendency to become prematurely 'old' from a psychological point of view. People who rely heavily on identity accommodation overreact to even small and seemingly unimportant changes, such as assuming that a small error of memory is a sign of impending senility. Instead of using the experience as an instigation to learn new memory strategies, when the problem reoccurs, the individual who overuses identity accommodation simply gives up and concludes that there is no point to fighting the inevitable. Thus, what is essentially an adaptive process becomes twisted into a process that cascades toward even greater losses and further negative changes in identity.

As adaptive processes, identity assimilation and identity accommodation both have virtues, but they also carry significant dangers. The ideal adaptive approach incorporates both processes, and is called identity balance. Individuals who use identity balance maintain a stable sense of self in confronting age-related changes while nevertheless findings ways to make necessary changes that ensue from these changes. This dynamic balance or equilibrium between assimilation and accommodation is associated with positive self-esteem.

Cultural factors may also play a role in affecting the individual's use of identity processes and the impact of these processes on self-esteem. Older Americans may be particularly likely to use assimilation, which is, in many ways, the kind of 'can-do' stoicism predominant during their formative years of early adulthood in the Depression and World War II years. By contrast, older adults who spent their youth in war-torn Europe may have adapted to the constant levels of stress associated with living under constant siege by developing a more pessimistic approach, in which accommodation becomes the predominant mode of adapting to negative experiences.

In general, positive affect toward one's life is related to a lack of preoccupation with the past, involvement with family, and a turning outward rather than inward. In contrast, a focus on the past and involvement in one's own personal losses rather than involvement with family is a feature of poorer adaptation and lower levels of well-being. These findings counter what we examine next in relation to adaptation: the role of reminiscence, life review, and development of a sense of ego integrity.

Ego Integrity and Adaptation in Old Age

In addition to the development of an existential identity in later adulthood, Erikson proposed that the end of life brings with it concerns regarding ego integrity – the achievement of a sense of wholeness and completion in one's life and self. According to Erikson, the optimally adjusted older adult is one who has achieved a state of ego integrity and who can look at the past without regrets and the future without fear. Such an individual experiences a positive attitude toward life, accepts life for what it was, has a sense of accomplishment, and feels that if life could be lived over again, it would be done so without major changes. This sense of accomplishment and completion allows the individual to face death and not see it as a premature ending or even something to be dreaded. By contrast, older adults who feel that they did not fulfill their potential or who have a weak and fragmented sense of self are in

a state of despair. Such individuals constantly regret past decisions and wish they could live their lives over again. They fear death because it will occur before they have corrected their past errors.

At the intersection of identity with ego integrity can be seen very different sets of reactions to the aging process. The individual characterized by despair views each physical, cognitive, and social loss as a constant reminder of impending death. This individual will be constantly subjected to new threats and will need to resort to identity assimilation as a way of protecting the self from these threats. Conversely, the individual who has achieved ego integrity does not fear aging or the future and is able to respond to aging changes in a more balanced manner.

The state of ego integrity is one that is not easily achieved, particularly in a society that is characterized by an emphasis on materialistic and individualistic values. For older adults who have successfully adapted to prior life crises, the sheer number of losses and changes in old age presents a far greater challenge. A stable but flexible identity as well as a sense of acceptance of the life that has been lived appear to be the major factors involved in successful adaptation to the aging process. However, there may be multiple paths to adapting to the changes associated with the aging process. For some older adults who are more philosophically inclined (and perhaps who have the benefits of being more highly educated), a critical examination of the self in relation to past experiences may provide the impetus for movement into a final stage of self-integration. Other older adults may adapt successfully by taking a more active approach – engaging in behaviors that maintain their physical and cognitive functioning while giving little thought to the larger implications of the aging process for the sense of self (accommodation in the service of assimilation). Finally, there are those elders whose involvement in issues external to the self, such as family, religion, or other formal and informal roles, helps maintain their sense of optimism and purpose in life. In helping older individuals achieve a state of optimal adjustment, it is important to remember that there are multiple paths to successful adaptation, reflecting the continuity of the individual's lifelong personality patterns, social context, and adaptational demands.

See also: Productivity and Age; Psychological Well-Being; Religion and Spirituality; Self Esteem.

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Addiction: General

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Glossary

Drug – Any substance, neutral or synthetic, that by its chemical nature alters structure or function in the living organism.

Drug Addiction – Chronic and relapsing drug-taking behavior characterized by compulsive drug seeking and abuse and by long-lasting chemical changes in the brain. Drug seeking becomes compulsive, in large part, as a result of the effects of prolonged drug use on brain functioning and on behavior.

Drug-Taking Behavior – A neutral term that describes drug use, inferring that use of drugs can be explained in the same terms as any other form of behavior.

Psychoactive Drug – Any chemical substance that alters mood, perception, or consciousness.

Substance Abuse – Inappropriate or excessive drug-taking behavior to produce pleasure, to alleviate stress, or to alter or avoid reality (or all three); such use may be dangerous or undesirable to the individual or community.

Tolerance – A diminished response to the same dose of a drug as a result of prior use of the drug. Once tolerance sets in, more of the drug is required to achieve its initial effects.

Introduction

This article provides an overview of the nature of psychoactive drugs and their actions. It also describes advances in understanding of how drug addiction occurs, emphasizing that drug addiction is the function of chemical changes in the brain following drug use that alters functioning in a manner that results in dependence on a drug. The article concludes with a discussion of elder drug abuse, specifically focusing on prescription drug abuse/misuse and on drinking among the elderly.

Understanding Addiction as a Brain Disease

Addiction is more than frequent drug use. Recent scientific research provides strong evidence that drugs not only interfere with normal brain functioning but also have long-term effects on brain metabolism and activity. Those addicted to drugs experience compulsive drug craving and cannot quit by themselves. Treatment is necessary to end this compulsive behavior.

Repeated use of a drug results in chemical and molecular alterations in the brain, and such changes have become equated with drug dependence. Although a person can initially be introduced into using drugs because of genetic, psychological, and sociocultural

factors, once a drug is taken, the drug-taking behavior itself may promote continued drug-seeking behavior via the changes caused in the brain. Continuous drug use leads to a cascade of intracellular events that changes the excitability of cells and ultimately alters neuronal circuit activity. These alterations are believed to elicit changes that provoke acute positive reinforcing effects because of drug interactions with individual transmitter systems within the general reward circuitry of the brain (i.e., the limbic system). Long-term drug effects include tolerance, sensitization, dependence, and withdrawal. Because these changes in reward circuitry are neuroadaptations, drug addiction may be defined as a brain disease.

It is as if there is a switch in the brain that turns on at some point during a person's drug-taking behavior. This switch flips on at different points for different drugs and different individuals, but once it is on, it fundamentally changes the user from a drug user/abuser to a drug addict.

Drugs and Drug Effects

A scientific definition of a drug is any substance, natural or synthetic, that, by its chemical nature, alters structure or function in the living organism. This broad definition encompasses many chemical compounds, some of which have the capacity to induce an altered state of consciousness. A psychoactive drug is any substance that alters consciousness, mood, or perception. Psychoactive drugs can be grouped into five categories based on their behavioral effects: (1) sedative-hypnotic compounds, (2) behavioral stimulants, (3) narcotic analgesics (opiates), (4) antipsychotic agents, and (5) psychedelics/hallucinogens.

Drug effects, however, vary widely and are often unpredictable, depending on such factors as mood, expectations of what the drug will do, previous experience with the drug, the route of administration, the nature and potency of the drug used, and the setting in which it is used. What follows is a very brief description of some of the major psychoactive agents that are used to alter mood, perception, or consciousness.

Central Nervous System Depressants (Sedative-Hypnotics)

Sedative-hypnotic drugs depress the functioning of the central nervous system (CNS), resulting in a reduction of neural activity and level of awareness. They include barbiturates and non-barbiturate hypnotics, antianxiety agents (minor tranquilizers such as Valium or Librium), and alcohol, which is classified as a sedative-hypnotic because of its behavioral effects, but it is not structurally related to the barbiturates or other such compounds. Some of the better-known barbiturates are secobarbital (Seconal), pentobarbital (Numbutal), and methaqualone (Quaalude).

Physiologically, CNS depressants lower blood pressure and respiration, slow speech, and alter consciousness. Tolerance develops from use over a lengthy time period, and physical dependence may also occur. Most CNS depressants act on the brain similarly – they affect the neurotransmitter γ-aminobutyric acid (GABA). Neurotransmitters are brain chemicals that facilitate communication between brain cells. GABA works by decreasing brain activity. Although different classes of CNS depressants work in unique ways, ultimately it is their ability to increase GABA activity that produces a drowsy or calming effect.

Discontinuing prolonged use of high doses of CNS depressants can lead to withdrawal. Because they work by slowing the brain's activity, a potential consequence of abuse is that when one stops taking a CNS depressant, the brain's activity can rebound to the point that seizures can occur.

Central Nervous System Stimulants

CNS stimulants consist of a variety of chemical agents that vary in mechanisms of action and chemical structure. There are four categories of CNS stimulants: (1) behavioral stimulants, which include cocaine and amfetamines; (2) clinical antidepressants; (3) convulsants such as strychnine; and (4) general cellular stimulants, which include caffeine and nicotine.

Behavioral stimulants include amfetamines and cocaine. There are three chemically similar types of amfetamines: (1) amfetamine (racemic amfetamine sulfate, formerly Benzedrine), (2) dextroamfetamine sulfate (Dexedrine and Obetrol), and (3) methamfetamine hydrochloride (Desoxyn).

Amfetamines cause an increase in heart rate and body temperature and can raise both systolic and diastolic blood pressure, increasing respiration and circulation. Pupils, blood vessels (vasodilation), and the air passages of the lungs (bronchodilation) are dilated.

Methamfetamine is a CNS stimulant chemically related to amfetamine, but its CNS effects are greater. Usage of methamfetamine has increased in recent years. Crystal meth is an extremely pure form of methamfetamine (between 98 and 100%). Methamfetamine releases high levels of the neurotransmitter dopamine, which stimulates brain cells. It also appears to have a neurotoxic effect, damaging brain cells that contain dopamine as well as serotonin.

Over time, methamfetamine appears to cause reduced levels of dopamine, which can result in symptoms like those of Parkinson's disease.

Methamfetamine causes increased heart rate and blood pressure and can cause irreversible damage to blood vessels in the brain, producing strokes. Other effects of methamfetamine include respiratory problems, irregular heartbeat, and extreme anorexia. Its use can result in cardiovascular collapse and death.

Cocaine is an alkaloid obtained from the coca plant. Cocaine is a short-acting but powerful stimulant similar in many ways to amfetamines. Crack is cocaine mixed with non-volatile chemicals to create a 75% cocaine paste.

Cocaine's physical effects include constricted blood vessels, dilated pupils, and increased temperature, heart rate, and blood pressure. It is known to produce its effects by acting on structures deep in the brain associated with experiencing pleasure (i.e., the limbic system, which is rich in receptor sites for dopamine, a neurotransmitter). In the normal communication process, dopamine is released by a neuron into the synapse, where it can bind with dopamine receptors on neighboring neurons. Normally, dopamine is then recycled back into the transmitting neuron by a specialized protein called the dopamine transporter. If cocaine is present, it attaches to the dopamine transporter and blocks the normal recycling process, resulting in a buildup of dopamine in the synapse. As cocaine abuse continues, tolerance often develops. This means that higher doses and more frequent use of cocaine are required for the brain to register the same level of pleasure experienced during initial use.

Narcotic Analgesics (Opiates or Opioids)

The term narcotic has generally been used to refer to opium and opium derivatives that are obtained from the oriental poppy, but it has also come to include other drugs that are semisynthetic or wholly synthetic opiates. There are three types of opiates: (1) natural opiates, which are obtained directly from opium, such as morphine and codeine; (2) semisynthetic opiates, which are chemically prepared derivatives of morphine or codeine, such as Dilaudid (dihydromorphine), heroin, and Metopon (methyldihydromorphine); and (3) synthetic opiates, which are chemically synthesized analgesics whose effects are similar to morphine, such as propoxyphene (Darvon), methadone (Dolphin), meperidine (Demerol), and pentazocine (Talwin).

One of the major effects of opiates and opiate derivatives on the body is nausea and vomiting. Opiates stimulate a part of the brain called the chemoreceptor trigger zone (CTZ), which senses impurities in the blood and stimulates a center that causes vomiting. Opiates constrict the pupils, depress reflexes, and may lower blood pressure due to dilation of peripheral blood vessels. Flushing may be experienced and sweating usually occurs. Continued use of opiates is known to reduce sexual functioning, thought to be associated with a decrease in the level of sex hormones in both genders. Opium and its derivatives can remain in the body for 2–3 days.

The CNS contains specific receptor sites for natural opiate-like chemical substances (endorphins, enkephalins, etc.) that specifically abound in the limbic system, and opioids interact with these receptors. These receptor sites are not the normal postsynaptic receptor sites involved in synaptic transmission – they are special proteins to which narcotic drugs are attracted, and it is postulated that these sites can also be occupied by heroin, morphine, and other opiate derivatives. The binding of a narcotic drug to these receptor sites, which is believed to cause an inhibition of the release of dopamine, norepinephrine, serotonin, and other neurotransmitters, seems to be the preliminary step in the initiation of both physiological and behavioral effects, but exactly how these effects occur remains to be discovered.

Hallucinogens (Mind-Altering Drugs)

Hallucinogens or psychedelics refer to the different classes of drugs that involve visual, auditory, or other hallucinatory experiences, and that create a sensation of feeling separated from reality. They achieve their effects chiefly by disrupting the interaction of nerve cells by interfering with the transmission of serotonin. Distributed throughout the brain and spinal cord, the serotonin system is involved in the control of behavioral, perceptual, and regulatory systems, including mood, hunger, body temperature, sexual behavior, muscle control, and sensory perception. Common hallucinogens include lysergic acid diethlamide-25 (LSD), psilocybin and psilocin, mescaline, and phencyclidine (PCP).

Marijuana

Marijuana is derived from the dried and chopped-up leaves, flowers, stem, and seeds of the hemp plant. More than 400 closely related chemicals have been isolated from the cannabis plant, which are collectively called cannabinoids, of which THC (delta-9-tetrahydrocannabinol) is believed to be the primary psychoactive or mind-altering compound. Today's marijuana is much more potent than that used in the early 1970s, up to greater than 30% more potent in some instances, and as the potency of the plant

increases there is a corresponding increase in its psychopharmacological effects.

Volatile Solvents (Inhalants)

Volatile solvents or inhalants are chemicals whose vapors, when inhaled, can produce psychoactive effects. Many of these chemicals are industrial solvents or aerosols, not pharmacological remedies. The pharmacological chemicals included in this category are anesthetics and other compounds that are inhalable. Volatile inhalants are grouped into three categories: organic solvents (hydrocarbons), volatile nitrates, and nitrous oxide.

The effect of these chemicals is a rapid general depression of the CNS. Chemical solvents can be highly toxic, and death or severe physical damage can result from their use. Death occurs from liver, kidney, bone marrow, or other organ failure; asphyxiation; paralysis of breathing mechanisms; or accidents as a result of being inebriated. Continued use of these drugs can lead to kidney, liver, lung, and brain damage.

Look-Alike Drugs

Look-alikes are psychoactive drugs whose name or appearance suggests psychoactive effects similar to another psychoactive drug. Many look-alikes are sold as drugs of deception and do not contain the drugs they are represented to be. Look-alikes generally consist of three substances: caffeine; ephedrine (or pseudoephedrine), a CNS stimulant; and phenylpropanolamine (PPA), a bronchodilator and respiratory decongestant. The substitute or look-alike drugs can cause serious side effects, ranging from sleep disturbances to psychotic episodes.

Club or Designer Drugs

Designer drugs mimic the effects of illegal drugs. Thirty-five variants or analogs have been synthesized from PCP. Several dozen analogs of methamfetamine have also been produced. Ecstasy, MDMA (3-4 methylenedioxy-methamfetamine), is a synthetic, psychoactive drug chemically similar to the stimulant methamfetamine and the hallucinogen mescaline. Research suggests that chronic MDMA use can lead to changes in brain function, affecting cognitive tasks and memory. MDMA can also lead to symptoms of depression several days after its use. These symptoms may occur because of MDMA's effects on neurons that use the chemical serotonin to communicate with other neurons. The serotonin system plays an important role in regulating mood, aggression, sexual activity, sleep, and sensitivity to pain.

Prescription Drug Abuse and Addiction: The Elderly at Risk

The non-medical use or abuse of prescription drugs is a serious and growing public health problem. According to the Center for Substance Abuse Treatment, "substance abuse, particularly of alcohol and prescription drugs, among adults 60 and older is one of the fastest growing health problems facing the country. Yet, even as the number of older adults suffering from these disorders climbs, the situation remains underestimated, underidentified, underdiagnosed, and undertreated" (2001: 1).

Prescriptive drug abuse or misuse occurs when people, purposely or accidentally, use medications in a manner that deviates from the recommended prescribed dose or instruction. Misuse may include overuse because of a belief that more is better, as well as underuse due to cost issues or as a method to avoid side effects. Abuse of prescribed or over-the-counter (OTC) drugs occurs when a person continues to use the drug even when it is not required for the primary purpose for which it was recommended, or when the person takes it in greater than recommended amounts because of its psychotropic effects.

The elderly are particularly vulnerable to prescription drug abuse or misuse because they tend to be prescribed more medications than necessary to treat their conditions than younger persons. Additionally, the onset of dementia in its various forms contributes to confusion about what, when, and how much medication needs to be taken. Many elderly people need help to take their medications correctly.

Although many of the prescribed drugs have the potential to be abused or misused, three types of drugs are chiefly involved in elder abuse: opioids, frequently provided for pain relief; CNS depressants, prescribed for anxiety and sleep disorders; and stimulants, prescribed to treat sleep disorder narcolepsy and attention-deficit hyperactivity disorder (ADHD). These three drugs, as described earlier, have the capacity to alter the brain's activity, leading to addiction.

Older people may be prescribed more drugs than they require because of the way drugs are now marketed (i.e., advertised in a manner that guides persons to ask their physician to prescribe a specific drug for a given condition), resulting in doctors writing scripts to satisfy their patient's demands. Additionally, the increasing number of medicines being prescribed for a variety of health problems, many of which can easily be obtained from online pharmacies, also contributes to elder misuse of prescriptive drugs. Most of these online pharmacies are legitimate businesses that provide an important service, but

some dispense medications without a prescription and without appropriate identity verification.

A variety of other factors also influences the use and potential for misuse or abuse of psychoactive prescription drugs and OTC medications by older adults. The aging process, with its physiological changes, accumulating physical health problems, and other psychosocial stressors, makes prescription drug use both more likely and more risky.

Further, older people are more likely to be prescribed long-term and multiple prescriptions that can lead to unintentional misuse. The elderly are also at risk for prescription drug abuse because they may unintentionally take medications that are not medically necessary. In addition to prescription medications, a large percentage of older adults also use OTC medicines and dietary supplements. Because of the high rates of comorbid illnesses in the elderly, changes in drug metabolism with age, and the potential for drug interactions, prescription and OTC drug abuse and misuse can have more adverse health consequences among the elderly than are likely to be seen in a younger population.

Elderly persons who take benzodiazepines are at increased risk for cognitive impairment associated with such use, leading to possible falls (causing hip and thigh fractures), as well as vehicle accidents. However, cognitive impairment may be reversible once the drug is discontinued.

A variety of health-care system-related and environmental factors helps to place older adult users of psychoactive prescription drugs at risk for misuse of these substances, serious adverse effects, or abuse and dependence. Potentially dangerous prescribing practices include ordering medications without adequate diagnoses or other documented indicators of symptoms, prescribing them for too long a time without appropriate medical monitoring of drug reactions and patient compliance with the prescribed regimen, selecting drugs known to have a high potential for side effects in older adults at the doses given, ordering drugs without knowing or reviewing whether they interact adversely with other medications the patient is taking, and failing to provide adequate and comprehensible instructions for patients regarding how and when to take medications and what side effects to expect and report. Drug misuse also includes failure to consider the influence of aging on the effects of drugs in the body.

Alcohol and Aging

Drinking is continuing to be recognized as a problem among the elderly. Although there are similarities in the drinking practices of older and younger drinkers, the problem presents a specific difficulty because there is a difference in the way older and younger people respond to alcohol. This difference stems from the physiological changes associated with the aging process. Additionally, people 65 and older tend to be affected by at least one chronic disorder that makes them more vulnerable to the adverse effects of drinking than younger people.

Risk factors for alcohol abuse include the following:

1. Gender: Research has indicated that older men, compared to older women, tend to develop drinking problems. Older women are less likely to drink, and among those who drink, they tend to drink less heavily than older men.
2. Loss of spouse: Drinking has been found to be more prevalent among older adults who have been separated or divorced and among widowed men.
3. Other losses: Other types of losses that contribute to drinking among older people are the loss of family members and friends to death, the loss of a sense of self-worth due to retirement, diminished mobility, impaired sensory capabilities, and declining health. Drinking, in many instances, may be a way to cope with the grief associated with such losses. Loss of independence, when the need to be placed in a caregiving facility arises, is also a factor related to the onset of drinking.
4. Earlier drinking and/or drug abuse: Having experienced a drinking or drug-related problem earlier in life presents a significant risk factor to resumption of former drinking or drug use. Such resumption may be related to the stress associated with aging, exacerbated by one or more of the types of losses noted earlier.
5. Family history of alcoholism: Research clearly indicates that drinking behavior is genetically influenced, thereby placing a person with a history of family drinking at risk for drinking-related problems throughout life.

Concluding Remarks

Drugs, in one form or another, have been available since the dawn of civilization, and they have been used for different purposes in different cultures. Many of the substances were, and continue to be, employed for their medicinal qualities. Today, however, because of the pharmacological revolution that is taking place, many more drugs are available. It is important to be aware of the nature of drugs, their psychopharmacological effects, and the adverse reactions that they can induce, especially among the elderly.

See also: Alcohol and Drugs; Pharmacology.

Further Reading

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Adult Education

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Glossary

Education – The process of acquiring abilities, skills, experiences, and knowledge systems as well as the results of this process.

Formal Learning – Learning in institutional contexts, with structured objectives, contents and methods, and which evaluated, documented, and certified.

Informal Learning – Learning that results from daily activities in the context of work, family, and leisure time, and which does not have structured objectives, contents, methods or evaluation.

Life Competencies – Experiences, strategies, and knowledge systems that people have acquired in earlier phases of their life span that enable them to maintain or reestablish a personally satisfying perspective on their life when confronted with serious problems, tasks, and challenges, in later years.

Introduction

The term education describes the process of acquiring abilities, skills, experiences, and knowledge systems as well as the results of this process. Specific contents of education reflect general cultural values and preferences of social environments and milieus, social change, and societal progress. Analyses of social environments and milieus confirm marked differences in formative educational experiences during childhood and youth, expectations and subjective conceptions of education, interests and barriers in extended vocational and general education, demands for methods and atmosphere, interest in educational content related to personality, health and key qualifications, competence, and informal learning, and the subjective attractiveness of alternative providers of education. Since the contents of education necessary for success in a given culture change continuously – it is assumed that the knowledge of mankind doubles approximately every 40 years, and in some economic sectors as often as every 6 months – educational activities can neither be concentrated in nor restricted to a single phase of the life span.

Interest in individual educational activities in adulthood is determined by lifelong interactions between opportunities and the necessity to learn new things and by the degree of openness to new experiences and knowledge systems. A comprehensive understanding of education is not confined to the acquisition of knowledge systems, but considers explicitly the abilities, skills, and experiences essential for creative ways of using knowledge to cope effectively with actual and (potential) future tasks and challenges. Moreover, the significance of education for the development of the individual is confined neither to his or her working life nor to the occupational sphere. In addition to occupation-related aims such as economic growth, maintenance or enhancement of innovative potentials, and individual employability, independence, self-determination, and social participation are principal aims of education in adulthood and old age to support the realization and perfection of a multitude of individual leisure activities and interests.

A comprehensive understanding of education should consider formal, non-formal, and informal learning. Formal learning typically refers to institutional contexts and is structured in terms of educational objectives, contents, methods, and evaluation. Formal learning is regularly documented and certified. By contrast, non-formal learning results from

daily activities in the context of work, family, and leisure time and is not structured by learning objectives, contents, methods, and evaluation. The main difference between non-formal and informal learning is that the latter refers to unstructured learning processes outside educational institutions, but is not systematic or intentional.

Education also comprises exchange processes among equal partners in social interaction in everyday life. On the condition that the experiences of older people are taken seriously, even apparently incidental intergenerational contacts might offer opportunities for the younger generation to benefit from older people's creative modes of successful coping with tasks and challenges. Accordingly, the possibilities and limits of a more effective use of the potentials of intergenerational learning are related to the socialization of old age in society. In this regard it is of particular importance whether old age and aging are constructed and represented as a social problem and whether negative stereotypes of old age and aging are salient in intergenerational contacts.

Life Span Development and Education

From an educational perspective, life span development can be described as a continuous and active process of coping with developmental tasks, i.e., demands, challenges, and chances that depend on people's environment and life situation in given phases of the aging process. Specific developmental tasks are conceptualized as a consequence of the interaction between biological maturity, normative conceptions of successful aging, or development in society and individual plans, aims, needs, and values. The significance of environment and life situation for life span development is twofold: first, coping successfully with demands of the environment and life situation increases the potential for coping with future demands and initiates further development; second, chances offered by environment and life situation contribute to the realization of specific developmental gains.

Aging implies different processes of change in different dimensions of the person. In each dimension, gains and losses can be observed simultaneously; changes in one dimension are a poor predictor of changes in other dimensions. Accumulated and organized experiences, knowledge systems, and strategies for coping effectively with familiar problems and tasks are important developmental gains (in the sense of psychological growth) in older adulthood. Important developmental losses do occur in physiological and neurophysiological functions and processes, e.g., cognitive flexibility, ability to cope with unfamiliar problems and tasks, and speed of information processing. Education is a precondition for reaching developmental gains, for the opportunity to compensate for developmental losses (e.g., via the process of selective optimization with compensation), and for individuals to maintain or reestablish a satisfying perspective on life in old age.

Four conclusions regarding education in old age can be drawn from the results of life span developmental psychology:

1. Accumulated and organized experiences, differentiated knowledge systems, as well as effective strategies for coping with tasks and problems and for taking the chances offered by environmental conditions and life situation must be understood as a consequence of education in earlier phases of the life span, i.e., active coping with tasks, demands, challenges, and chances in younger years. In this context, the continuity of lifelong development becomes clear, since achievements in earlier years extend to later years as long as they are used sufficiently.
2. The use and further improvement of experiences, knowledge, and strategies for effective action are essential for the realization of developmental gains in old age. This fact emphasizes the importance of education in old age. Generally, there is a sufficient amount of plasticity, i.e., capacity to learn and change. As a consequence, education in old age, aiming to contribute to the use and further improvement of experiences, knowledge, and strategies for effective action, should be able to contribute to effective coping with developmental tasks and successful aging. There is a demand for education in old age, since people cannot cope successfully with developmental tasks or realize the potentials offered by cultural innovation (e.g., in technical fields) in old age without engaging in a process of coping with self, life situation, and environment.
3. Education in old age must not be analyzed only in terms of possible gains, depending on development in earlier phases of the life span; possible developmental losses are of equal importance. In this context, two aspects should be considered. First, gerontological research could show that cognitive training has an impact on the decline in the mechanics of human intelligence, i.e., the basic processes underlying intellectual performance. Moreover, through cognitive training, compensation for specific impairments and losses can be encouraged. Intellectual performance and everyday competence can be improved by new learning and memory strategies that compensate at least in part for deficits in sensory and motor functions. The selective optimization with compensation, i.e., the choice

(selection) of well-developed functions, skills, and strategies and their differentiation (optimization) with the aim of compensating for losses in other functions, skills, and strategies, forms an important basis of successful aging.

4. In the context of possible developmental losses, especially in very old age, decreases in health status and social integration as well as limitations of life expectancy should be mentioned. However, empirical findings show that even in the very old, most people are able to cope effectively with developmental losses and to maintain or reestablish a personally satisfying perspective on their life, exemplifying resilience in old age. It should be noted that resilience is established through personal and environmental resources. Concerning environmental resources, gerontological studies show that participating in cultural and social activities that offer stimulation and support promotes effective coping with developmental losses. These findings support an educational perspective that points to the significance of education for coping with critical life events, e.g., via providing information about effective coping strategies or institutional services. In the case of losses in certain functions and skills (e.g., visual impairment as a result of macular degeneration), compensation (e.g., use of audio cassettes or touch typing) as well as increased engagement in interests and activities that do not require these functions and skills can be interpreted in two ways: as a process of education and as encouraged by educational activities. Several intervention studies show the possible impact of educational opportunities on the effectiveness of individual coping processes. From the understanding of education and its effects, the close relationship between education and competence becomes clear. The latter is defined as the skills and abilities to maintain or reestablish an independent, task-oriented, and personally meaningful life in a stimulating, supportive (physical, social, and infrastructural) environment that encourages self-responsible coping with problems, developmental tasks, and challenges.

Education and Employability of Older Employees

The principal findings of international studies on working performance and possible training gains in older workers can be summarized in the following 10 points.

1. Most studies find an inverted-U relationship between chronological age and working performance. The peak of performance is reached between the ages of 30 and 40 years, and performance in old age converges to the performance of 20-year-olds. Similar findings are reported for driving, for which perceptual losses account for decline in performance.

2. Age differences in occupational performance are small. Training measures can compensate for age-related slowing. Training is a better predictor of performance than chronological age. In many cases age effects prove to be reversible through adequate training measures.

3. Age differences can be observed in less-experienced workers. If any age differences are found between experienced employees, the differences are only of a small magnitude.

4. However, in the cognitively most challenging professions, experience cannot compensate for age-related deficits. Complex tasks that require extended information-processing capacity regularly show some age-related deficits.

5. Previous knowledge can effectively compensate for losses in working memory. The working memory resources required for the process of thinking ahead can be assisted by using previous knowledge to structure information processing.

6. The performance of older experts regularly reflects successful compensation for age-related decline in some components through improvement in other components (knowledge, strategies). Experience with occupational tasks and challenges can be used to compensate for age-related decline, particularly in complex tasks. In some tasks the peak of performance is reached only in older years because accumulation of relevant knowledge and expertise requires long learning processes. By contrast, the performance of simple tasks often cannot be improved upon by using acquired strategies and knowledge systems. Leadership is a prototypical example for the particular potentials of older employees. Older managers are often more successful in comparison to younger managers because they take more time for important decisions, which reflects a more extensive use of relevant information, flexibility, prudence, and self-criticism.

7. Practice is an essential precondition for development and maintenance of expertise over the life span. For supreme performance, musicians need at least 10 years or 10 000 hours of practice. Professional pianists show only some age-related decline under conditions of highly complex requirements on motor abilities. The same is true for older pianists who reduced their amount of practice in comparison to younger pianists.

8. Transfer of training gains depends on task-specific requirements. High specificity in content, personal relevance, and long-term time investment

are the general conditions of a successful training program. The development of a cognitive ability should be oriented toward those special strategies and detailed knowledge systems that underlie expert performance (cognitive engineering). Training gains are similar for guided and self-initiated learning.

9. The relationship between chronological age and performance follows different developmental paths; some kinds of performance even increase with age.

10. High levels of performance can be maintained when occupational tasks are adapted to the employees' individual preferences and working rhythms. As a consequence, changes in job placement and job profiles are promising strategies for companies to ensure continued employability of older workers.

Their expert knowledge often qualifies older employees for overseeing important tasks within the company. In the late 1980s in the United States, some companies attempted to motivate retired senior executives to return to work and take responsibility for some tasks. This corporate strategy developed from the insight that the retirement of older employees often leads to a loss in expert knowledge for the company. This expert knowledge is seen as an important basis for successful reorganization of operating sequences and improvement of internal communication, as well as for familiarizing younger employees with their work.

Education, Health, and Competence

Numerous studies confirm a close relationship between health and education. Educational status proved to be a predictor of life expectancy and morbidity. Survey data indicate that as early as in younger adulthood, people with higher education – women somehow more than men – have an extended life expectancy and suffer less often from headaches, sore throat, stomach pains, and backache. Low social status correlates with morbidity and health-related stress. The aforementioned relationships are ascribed to different opportunities for leading a healthy life, occupational stress, competencies for coping with disease, habits in using health insurance, and communication with representatives of public health. Such explanations point to education as a mediator of possibilities to exert influence on one's own health status or to establish a relationship with medical practitioners that allows for codetermination in medical treatment in cases of disease. Intervention studies show that enhanced knowledge and patient training contributes to a lessened and more effective use of the health insurance system and improved compliance in people suffering from chronic disease.

Developing competences for maintaining health and effective coping with disease means acquiring the ability to express one's needs, wishes, and expectations, to catch up on relationships and opportunities, to choose, to decide, to judge, to codetermine, and to control.

For older women and men, staying healthy is one of the most important aims in life. Analyses indicate that the subjective importance of health steadily increases over the life span and that there is no sphere of life in old age in which people are as engaged as in the maintenance and improvement of health. Consistent with this finding of empirical research, contemporary cohorts of older people in Western societies in comparison with previous cohorts more often claim their rights for self-determination and self-responsibility with regard to the health insurance system. Lack of codetermination and self-management, deficits in the enforcement of patient rights, deficits in information and explanation and in transparency of services, bureaucratic structures and procedures, and being considered a patronized patient instead of a partner in medical treatment are aspects of the health insurance system that have been criticized empathically. The need for more self-determination and self-responsibility in dealing with the health insurance system is based on six principal findings:

1. Competent users of the health insurance system are able to soundly exhaust self-help potentials before making use of professional treatment.

2. Competent users of the health insurance system are able to cope effectively with their own disease, particularly chronic disease, and any necessary treatment in the sense of case management.

3. Competent users of the health insurance system are cooperative with regard to the consensually determined treatment and contribute to the prevention of misdirected medical resources due to a lack of compliance.

4. Competent users show a sense of responsibility toward the supportive society.

5. Competent users of the health insurance system develop a better understanding of medical and professional decisions as necessarily reflecting a scope of discretion. They are able to consider that in the light of medical progress and the competences and experiences of the individual practitioner, different decisions and judgments do not always imply a lack of quality in the health insurance system.

6. Competent users of the health insurance system develop a detachment from the public health system in the sense of minimized rates and length of contact by simultaneously keeping constant or improving outcomes in terms of morbidity, mortality, quality of life, and health costs.

The aforementioned competence in the use of the health insurance system is influenced by a magnitude of factors. These factors comprise personal resources such as the health-related self-concept and the experiences that people have had in coping with disease. Moreover, competence is influenced by environmental and social factors, such as which living and life conditions are available for leading a healthy life, how a given health insurance system is organized, and on which kinds of social and familial support people can rely when suffering from disease. Last but not least, educative, communicative, and informative factors play a role in individual coping with disease and in perceptions of internal control over maintenance or improvement of health.

Today, training programs to support a self-determined and self-responsible disease management have been developed for many chronic diseases. In addition to the acquisition of specific techniques, the establishment of consensually determined control of use of the health insurance system is another important part of such training programs. The patient is intended to learn what is relevant for the course of his or her disease, what he or she can do on his or her own, and in which cases it is necessary to consult a medical practitioner. Experiences from campaigns in the Netherlands and Germany show that educational programs can contribute to reduced consultation of medical practitioners in cases of coughs and sneezes.

Adequate communication is an indispensable precondition for participation and competence improvement. Difficulties in the communication between patients and medical practitioners are the most frequent reason mentioned for the consultation of patient-initiated counseling. Patients regularly have the impression that their concerns are not taken seriously and that medical practitioners do not offer enough information and explanation of medical treatment and potential alternatives. Older and disabled people in particular suffer from this impression, indicating that professionals often tend to assume a lack of competence and dependency from physical disablement.

With regard to health and competence, information comprises all measures to support the patients' acquisition of knowledge necessary to understand his or her own health status. Today, such information is available from numerous resources. This increase in the quantity of available information goes hand in hand with the risk of a decrease in quality of that information, implying a reduced usefulness of this additional information. The problem of receiving health-related information is increasingly replaced by the problem of adequately evaluating the quality of the available information. In Western societies patients are able to make use of the progress in information technology to access a vast amount of information on their diseases, alternatives in medical treatment, or preventive measures that makes them at least to some degree independent from medical practitioners' previous monopoly on providing information as well as from a costly investigation of literature for experts and laymen. Clear information about diseases, diagnostics, alternatives in treatment, and prevention could substantially strengthen patient sovereignty. According to data from the 1999 American Internet User Survey, 36% of all adult American Internet users (42% of female users) regularly look for information in the sphere of health and medicine. However, the quality of the information can seldom be assessed. The same is true for much health-related information available from the print media. As a consequence, services intended to strengthen patients' role as competent partners in the health insurance system must be offered by independent institutions on the basis of quality assurance.

Life Competencies of the Old as Human Capital

The term life competencies refers to experiences, strategies, and knowledge systems that people have acquired in earlier phases of the life span (i.e., understanding of education as a result of active coping with challenges and demands of environment and life situation in a given period of life). Life competencies are built up in the context of effective coping and enable people to maintain or reestablish a personally satisfying perspective on their life when confronted with serious problems, tasks, and challenges in later years. Building up life competencies in earlier years is a basic requirement for successful development in advanced age, i.e., effective coping with the demands of life in old age. Such demands include practical and psychological as well as interpersonal and ethical demands. Consequently, our understanding of life competencies is not limited to the experiences, strategies, and knowledge systems acquired in the context of occupational activities. Life competencies are also reflected in ethical judgments, voluntary activities, as well as the willingness and readiness to take responsibility for oneself, for others, or for society. Empirical findings show that active

coping with developmental tasks and the chances and limits of life can lead to the establishment of expert knowledge or wisdom with respect to questions of life. Expert knowledge or wisdom is not limited to old age but can be developed in earlier years as well. The only prerequisite for the development of expert knowledge or wisdom is the conscious and responsible preoccupation with a multitude of problems, tasks, and challenges in different periods of life and different contexts of development. Therefore, empirical findings support a perspective on lifelong educational processes that accentuates the development of the person rather than the cultivation of specific knowledge and skills.

The term human capital refers to the significance of life competencies for society and culture, i.e., processes of initiating societal and cultural change and the extent to which societal and cultural change is determined by life competencies of the old. Societal and cultural development depends on the possibility of using individual life competencies. It is here necessary to establish the infrastructural conditions, e.g., opportunities for volunteers to qualify and to use given experiences, strategies, and knowledge systems effectively.

Proceeding from a comprehensive understanding of productivity, several possibilities for leading a productive life in old age can be distinguished. Being interested in the development, living conditions, and vital interests of younger people, the transmission of information to younger generations, and the responsible reflection on experiences and knowledge systems of younger generations are examples of intellectual and emotional productivity in old age, since intergenerational discourses can initiate emotional and intellectual differentiation in older and younger participants. Moreover, by leading an independent and responsible life, even when confronted with serious problems or borderline situations, older people can give a good example to younger people of how to cope with problems and difficulties, i.e., build a productive context for others: an illustrative example of emotional and motivational aspects of productivity. Even the dialogue between young and old can be understood as an educational process in which young and old people can enrich each other by exchanging specific experiences and knowledge as well as general life competencies. For our understanding of education in old age, two conclusions can be drawn. First, older people are able to fulfill educational functions for others by offering skills, experiences, and knowledge or by leading an independent and responsible life that can be regarded as exemplary for younger generations. However, it should be mentioned that for fulfilling educational functions for others it is essential that the transmission of experience and knowledge is free from prejudiced beliefs that presuppose that one's own knowledge is superior to the knowledge of other people and that, therefore, others have to be instructed to adopt one's own experiences and knowledge systems. Second, dialogue and discourse with younger people can initiate further development. Intergenerational discourse is an important means of realizing potential for development. From the reports of services and institutions concerned with education in old age, it seems obvious that intergenerational encounters – either informal or in the context of formal educational settings – do have a great impact on the developmental processes of both the young and the old and therefore should be promoted intensively. Stimulating an exchange between the young and the old by inviting older people to visit schools, participate in specific lessons (e.g., on history), and engage in the transmission of experiences and knowledge is appreciated equally by the young and the old. The challenge for educational practices in establishing intergenerational contact that enables people to realize and use their specific life competencies is twofold: first, experiences, strategies, and knowledge systems must be explored and integrated systematically, and second, discussion or discourse must be initiated and guided with methodological competence.

Lifelong Learning

In past decades, the traditional understanding of education, which was exclusively oriented toward formal learning in childhood and young adulthood, has been broadened to the concept of lifelong learning. Different versions of this concept have in common the idea that learning in different phases of the life span, learning in formal, non-formal, and informal contexts, as well as learning in the context of a variety of personal experiences are indispensable components of lifelong learning. However, there may be changes in form, content, and motivation. In childhood and young adulthood, formal learning in school and professional training are most common. Decisions concerning the course of education are during childhood primarily made by the parents, whereas independent decisions continuously increase during the transition to adulthood. Inequalities in educational opportunities are determined by differences in social status. In the context of professional training, education focuses on aspects of utility for future working activities, whereas in school there is a focus on general education. In working life, non-formal and informal contexts become more

important as compared to formal contexts, admittedly not for all workers in all jobs. Employees in positions with many opportunities for independent and self-responsible decisions benefit from opportunities for further learning. By contrast, the competence of employees who must perform unchallenging, repetitive, and monotonous activities without opportunities for independent and self-responsible decision making decreases due to a lack of stimulation and deficits in extended vocational training. Because individual resources are restricted and tied to diverse obligations in adulthood, these employees cannot evade decreases in employability. The pressure of immediate utility, which is characteristic not only for learning during working life but also increasingly for learning in young adulthood, is no longer important in retirement. However, retirement implies the loss of the learning contexts of working life. This loss can admittedly be compensated for by activities of civil engagement. On the one hand, there is the opportunity in old age to use the new freedom to study further in accordance with personal hobbies, interests, and aspirations. This kind of learning might open up new areas of activity. On the other hand, maintenance of health and independence requires continuous learning processes.

Proceeding from the aforementioned aspects of lifelong learning, the 1972 Faure report suggested a comprehensive definition of educational aims, i.e., the establishment of a physical, mental, emotional, and moral human entity. The previous definitions of lifelong learning are a good starting point for a more comprehensive understanding of learning in occupational contexts and retirement. However, they focus too much on professional training and working life by accentuating aspects of utility and job mobility. The concept of lifelong learning can be explicated by seven points:

1. Lifelong learning encompasses the totality of all formal, non-formal, and informal learning over the entire human life cycle.
2. Lifelong learning implies different educational paths that are simultaneously permeable and interconnected.
3. Lifelong learning implies independent and responsible learning, and independence and responsibility themselves must be learned.
4. Lifelong learning implies learning in a manifold and transparent landscape of opportunities.
5. Lifelong learning implies enabling learning by the provision of sufficient resources.
6. Lifelong learning implies an investment of individuals, companies, and society.
7. Lifelong learning implies transparency, counseling, and quality management.

The necessity of lifelong learning in adulthood becomes particularly evident in the context of changes in life that can be described as discontinuities, e.g., parental leave, changes in occupation, and unemployment. In comparison to earlier phases of the life span, learning is less determined by institutional contexts. Due to occupational and familial commitments and obligations, there is a higher demand for programs that allow for a flexible adaptation of learning times, such as correspondence courses or computer-assisted learning. Qualifications and competences that were acquired via informal learning in occupational and familial contexts should be made exploitable by means of documentation and certification. The benefit of learning for the learner should be made obvious. Usage of modules from formal educational programs facilitates the development of individual profiles of competence. Moreover, a successful strategy of lifelong learning requires that companies and institutions responsible for education and job placement cooperate in a way that meets the challenges of transparency and counseling in the context of obligations and commitments in adulthood. Similarly, counseling must take into account the magnitude of professions as well as the variety of individual talents, interests, and life situations.

The necessity for intensifying the investment in lifelong learning follows from four principal aims: (1) the elevation of economic growth and improvement of competitiveness, (2) the support of individual employability, (3) the promotion of independence in old age, and (4) the strengthening of societal cohesion.

Aim 1: Due to demographic change and globalization of markets, the economic growth and competitiveness of Western societies increasingly depend on the innovative potential and qualifications of employees. As a consequence, there is a need to enhance the investment in education, including investment in extended vocational training for older workers.

Aim 2: Rates of employment and unemployment differ according to the level of qualification of the employee. In particular, those who reached a higher level of qualification and who continuously used opportunities for further education remain employed until retirement. This relationship has been no real problem for Western societies as long as losses in employability of older workers could be compensated for by opportunities for early retirement. However, demographic change limits the ability of younger

generations to guarantee economic competitiveness and Social Security benefits. For Western societies there is no alternative to an increased investment in the employability of older persons.

Aim 3: Good health and mental flexibility are central preconditions for leading an independent and personally satisfying life in old age. Numerous studies confirm that everyday competence as well as physical and mental capability can be improved by adequate training programs. Moreover, programs proved to be effective regardless of the age or mental and physical capacity of the participants. Results from empirical studies suggest that people suffering from dementia might benefit from a combination of psychomotor and memory training. The protective effects of physical activity are well supported, even in the oldest age groups. The significance of lifelong learning is apparent from the fact that healthy lifestyles have a lifelong protective effect. Consequently, educational programs for younger age groups that contribute to the awareness of the relationship between health status in old age and health-related behavior in earlier phases of the life span should be regarded as an important contribution to prevention for old age. In addition to such prevention for old age, prevention in old age also has considerable effects. As a consequence, the implementation of educational programs designed primarily for older people is a central part of a strategy of lifelong learning. Educational programs supporting health and capability (not exclusively for older people) are offered not only by traditional institutions but increasingly also by health insurance companies or sports clubs. Moreover, self-help groups are also important in this respect. Furthermore, the influence of the media should be considered. The media contribute, via mediation and accentuation of age stereotypes, to the endeavors that people undertake to shape their own aging process. In addition to this motivation or demotivation, a major function of the media is to enlighten people on medical relationships, health products, and health programs. Social inequalities in morbidity and mortality also reflect the significance of lifelong learning. A strategy of lifelong learning points to the necessity of promoting educational activities among members of underprivileged social strata. In this regard more group-oriented opportunities and contexts should be established.

Aim 4: General political and cultural learning mediates basic orientations and competences that are a precondition for social participation in a continuously changing complex society. The contents of learning are essential for civil engagement in all phases of the life span. Without this engagement, social cohesion and security in modern societies would be impossible. A general education is a precondition not only for occupational training and extended vocational training, but also for independent and responsible decisions concerning professional and private life. Personal responsibility for participation in lifelong learning opportunities, including the financing of this participation, cannot simply be presupposed. Instead, personal responsibility for lifelong learning develops from successful participation and positive experiences. In multicultural and multi-ethnic societies, belonging to a cultural minority regularly goes along with inferior educational opportunities. A large proportion of illiterates among foreigners might be a minor problem in industrial societies where blue collar jobs are essential for the gross national product. However, in modern societies, a lack of education mortgages access to the labor market, precludes people from social participation, and therefore implies a serious risk for social cohesion.

A principal challenge for a future-oriented educational system is to develop attractive services for the oldest age groups and for people from underprivileged social status groups. Moreover, the special interests of those older people who have been already engaged in lifelong learning activities must not be neglected. This is particularly important with regard to higher educational status in later-born cohorts of older people. In addition to senior academies and universities, other initiatives that try to integrate older people into regular courses of universities are promising. Finally, an efficient educational system considers the continuity of individual motivation for education over the life span. The successful realization of a strategy of lifelong learning depends on society's ability to motivate younger people to continuously invest in general education. The establishment of a broadened spectrum of interests in the younger years is seen as an important part of prevention for old age. Numerous studies suggest that establishing and maintaining life satisfaction in old age is supported by opportunities for new or extended engagement in interests and activities that have been built up and developed in earlier phases of the life span.

See also: Education and Aging; Learning; Life Span Theory; Work and Employment: Individual.

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Age Stratification

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Glossary

Age – Refers to both people and their social structures. For people, age marks how much of their lifetime has so far been lived. In social structures, age denotes criteria both for performing in roles and for entering and leaving them. It operates in complex ways to locate people of every age in society.

Age-Graded Roles – Positions in social structures (e.g., work or nursing homes) for which age (or some substitute for age such as physical strength) is used as a criterion for permitting or proscribing role occupancy, entry, or exit, or for defining role expectations or sanctions for performance.

Age Strata – The rough divisions by age of people from younger to older within a society or group. Age strata reflect socially significant aspects of people and are only partly defined by biology.

Aging – Interacting biological, psychological, and social processes that start with birth (or conception) and end with death. The term is widely used to refer to the biopsychosocial changes in later phases of the life course.

Birth Cohort – A set of people born at approximately the same period of time. Members of a cohort in a society thus experience a common slice of history. Through cohort succession (or cohort flow), new members are continually born into a society, move up through the age strata as they grow older, and eventually die. As one cohort exits an age stratum, it is replaced by members of an oncoming cohort.

Demographic Transition – The transformation a society experiences as it moves from high birth and death rates to low birth and death rates. This transition in vital rates is generally associated with economic development. During this transition the population age structure shifts from one dominated by children to one in which old people comprise a large proportion.

Easterlin Effect – The hypothesis, first developed by the economist Richard Easterlin, that cyclical changes in demographic and social behavior are produced by fluctuations in cohort size. It is posited that large cohort size reduces economic opportunities for its members and that small cohort size offers advantages to its members.

Structural Lag – The situation in which the roles available to members of an age stratum are mismatched with the needs and preferences of individuals in the age stratum. In aging research, this involves a situation in which social structures (firms, schools, families) do not provide rewarding roles for the growing number of healthy, well-educated, long-lived people entering later life.

Introduction

Age stratification is a conceptual framework for exploring both how individuals age over the life course and what meaning is given to age in a society. This framework was developed by Matilda White Riley and her associates in the 1970s, and the term is still identified with her name. As a conceptual orientation, age stratification gives attention both to the individuals who occupy the various age strata in a population and to the social structures that use age to shape the behavior of those individuals. It gives special attention to changes over time in the experience of aging and to changes over time in relationships between age strata. This perspective insists that we recognize that human aging is, to a large extent, socially constructed. An important implication of this perspective is that the ways in which individuals age can and do change over time. In view of the breadth

of the perspective and also in view of the sometimes confusing and multiple connotations of the general concept of stratification, Riley later preferred to call it the aging and society perspective.

Age Strata in a Population

Age is a universal feature of individuals, and each population can be described in terms of its age composition. Although the meaning of age differs across societies, age is always socially significant. Therefore, the age composition of a population has social relevance.

Age Composition

The age composition of a population provides a starting place for discussing age stratification, and the population pyramid provides a simple way to picture the age composition of a population. Populations pyramids are shown in **Figure 1** (depicting the US population in 1900 and in 2000) and **Figure 2** (depicting the populations of Kenya and Spain in 2000). In each of the population pyramids, the percent of the population in the various age strata is shown by horizontal bars stacked on top of each other, with the youngest age category on the bottom and the oldest on top. This graphic depiction of a population

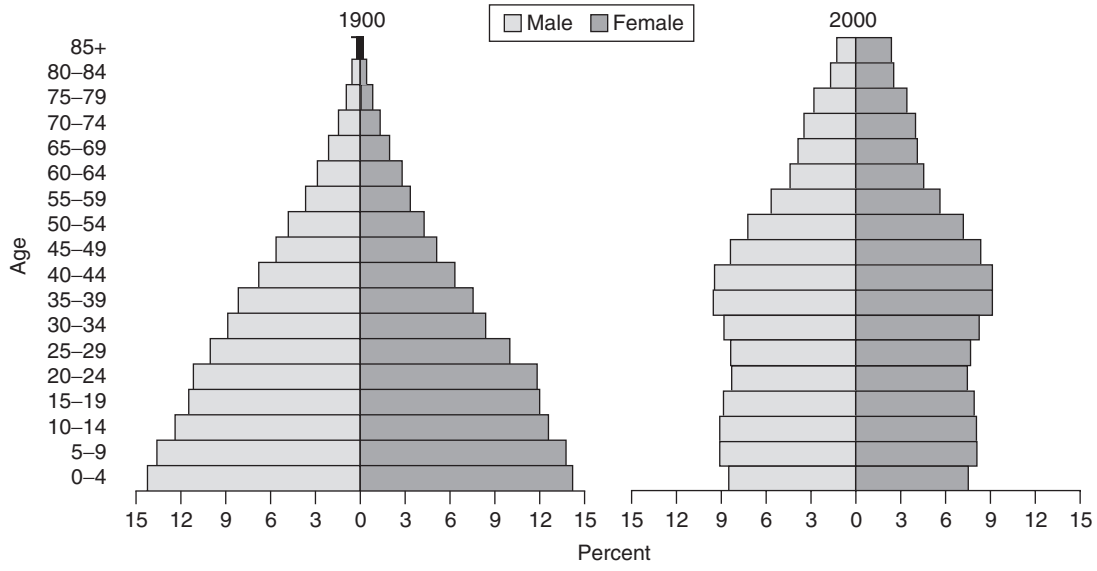

Figure 1 Age and sex distribution of the US population, 1900 and 2000. Source: US Census Bureau, decennial census of population, 1900 and 2000.

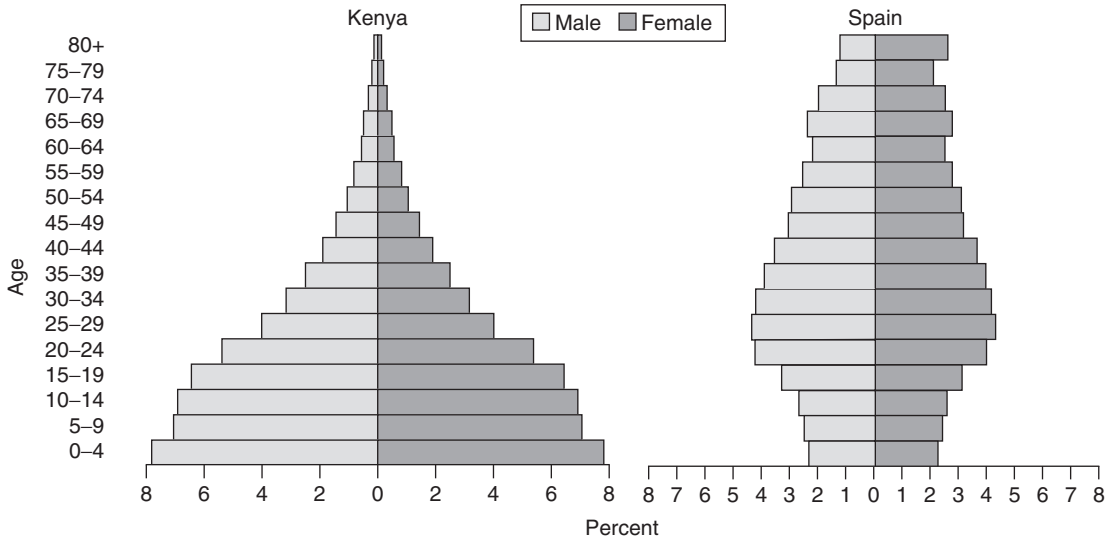

Figure 2 Age and sex distribution of the populations of Kenya and Spain, 2000. Source: US Census Bureau, International Database.

immediately suggests one aspect of age stratification in society – the population may be viewed as layers of people based on chronological age. By convention, each age stratum in the population pyramid is divided by sex, with males on the left and females on the right. The term pyramid clearly was derived from the typical shape of population age composition in high-fertility societies – the age composition of populations in low-fertility, late modern societies does not resemble a pyramid.

The dramatic changes occurring over time in the relative size of various age strata in populations of the economically more developed societies is well known. Using the example of the United States, the population over age 65 increased from 4.1% in 1900 to 12.4% in 2000, and is expected to exceed 20% by 2040. Equally dramatic is the contrast between contemporary societies that are at different stages of development (illustrated by Kenya and Spain). In Kenya's population, the ratio of children under age 15 to people over age 65 is 17.5; in Spain, this ratio is 0.9. Demographic analysis can explain why the age distribution of populations varies so much across societies and over time. At any point in time, the number of individuals in a population who occupy each age category is determined by past patterns of fertility, mortality, and migration. Migration patterns tend to have only a minor impact on the age composition of a population, so the large transformation in the age composition occurring over the past hundred years must be related to declining death rates and, especially, declining birth rates. In societies with sustained high fertility, young people dominate the population; in societies in which fertility has declined to near or below replacement level, old people comprise a significant proportion of the population. Past and future population aging, the increase in the proportion of the old and the decrease in the proportion of the young in a population, has profound implications for all societies that experience the demographic transition. However, as the age stratification perspective seeks to elucidate, what these implications are depends not only on the relative size of age strata, but also on the characteristics of the individuals in them and on the social meaning of age.

Characteristics of Individuals in Age Strata

Even a casual observation of a population reveals that age strata differ not only in size, but also in the social and physical characteristics of their members. For example, in the United States in 2000, younger males slightly outnumbered females, but at the oldest ages females greatly outnumbered males (**Figure 1**). Other examples of differences across age strata in the United States around 2000 are in the proportions of racial/ethnic minorities (24% of the population under age 5 years were minorities, compared to 13% of those aged 70–74), and in the average educational attainment level (12% of the population aged 35–34 had less than a high school education, compared to 33% of those aged 75 and older). Of course, the explanation for these differences between younger and older age strata cannot be attributed to intrinsic biological aging – individuals do not become whiter or less educated as they age. Some differences across age strata, such as intellectual functioning and physical ability, are generally assumed to be related to effects of biological aging. But a satisfactory explanation of the differential composition of various age strata at a particular time requires tracking the experience of birth cohorts as they age through unique historical contexts.

Differences between age strata can be illustrated by comparing those aged 75–79 in the United States in 2000 with those aged 45–49. Individuals in the age category 75–79 were born in 1921–25, were children during the Great Depression, and were becoming parents during the Baby Boom. Individuals aged 45–49 in 2000 were born during the Baby Boom years of 1951–55, were children during a period of economic prosperity, and encountered a tight labor market as they entered young adulthood. A comparison of several social and biological characteristics of these two age strata in 2000 is shown in **Table 1**. Why do these age strata differ so markedly in educational attainment, marital history, sex ratio, childlessness, prevalence of physical disability, and race and ethnic classification? The aging and society perspective argues that the answer to this question requires an examination of how social forces in the past differentially shaped the life course development of these cohorts. For example, the differences in educational attainment reflect differences in the educational institutions encountered by these cohorts as they moved through childhood. A variety of

Table 1 Percent of individuals aged 45–49 and 75–79 in 2000 with selected characteristics

Characteristic	*Percent aged 45–49*	*Percent aged 75–74*
Less than a high school education	11	29
Female	51	59
Ever divorced	35	18
Childless	16	11
With a disability	9	24
Non-white	18	11

Source: US Census Bureau.

historical, social, and economic forces affected the marital and childbearing experiences of these two cohorts. The differences in racial and ethnic composition and in sex ratios reflect, in part, the social conditions that led to differential survival experience of different segments of the population in the twentieth century.

It is quite apparent that the cohort born in 1950–54 experienced aging in the first half of its life course differently than the cohort born in 1920–24. Consequently, we can anticipate that when members of the younger cohort occupy the age category 75–79 in 2030, they will be substantially different from the cohort aged 75–79 in 2000. Even in terms of physical disability, it is unlikely that the older population in the future will replicate the experience of those who are currently old. When cohorts experience different lifestyles and different health-care systems as they age through life, their health status in old age is likely to be different.

Age and Society: Basic Social Systems Principles

The preceding discussion primarily focused on differences in the number and characteristics of individuals comprising various age strata. The age stratification approach further develops a model of aging and age differences by explicating the role of social structure in how individuals age.

Background: Age in Social Structure

As noted at the outset of this article, in gerontology the term age stratification remains largely synonymous with the extensive and influential work of Riley, who introduced the term in the early 1970s. Later, in the 1990s, Riley came to believe that the complex and multiple connotations of the general concept of stratification rendered the term confusing, and renamed her approach the aging and society perspective. Nevertheless, age stratification remains a widely used term, and it is largely synonymous with her approach and with her extensive and influential body of writings. The age stratification model played a significant role in stimulating researchers interested in aging to link theoretical and empirical analyses. It also has provoked critique and controversy, and these critiques are discussed after reviewing the basic model.

Before discussing the formulation of age stratification, it is important to understand the basic social science principles on which this approach is founded. In Riley's framework, aging as a property of individuals must be distinguished from the 'social fact' of age – that is, from the concept of age as a cluster of cultural representations and organizing principles of society. This analytical distinction that separates 'person' from 'role' is derived from Talcott Parsons' approach to social systems. Persons, of course, are individual human actors. In Parsons' framework, roles are not properties of persons; they are positions in social systems (e.g., families, communities, schools, corporations) that are occupied by persons. Especially when social systems are explicitly age graded, age is a feature not just of individuals, but also of the role structure and normative apparatus of a society.

Applied to the notion of age stratification, this differentiation has two important aspects, one that is static and one that is dynamic. In static terms, age stratification deals with the distinction between the age structure of roles and the age structure of a population. Its dynamic aspect highlights the contrast between age differences among individuals at a single point in time with the changes that occur to individuals as they develop and age over the life course.

Age Grading, Allocation, and Socialization

The population age structure refers to only one of the components of age stratification, the age-specific distribution of people. The age stratification framework also implies attention to the age-related aspects of the role structure of society and the problem of allocating or matching the available individuals with a finite number of available age-graded roles. When roles are rigidly age graded (as in the case of mandatory schooling for children, military conscription, or mandatory retirement), problems of mismatch or 'strain' can occur.

Age is built into the role structure of society when age is a criterion for occupying, entering, or relinquishing certain roles. Further, age can regulate how individuals are expected to perform their roles: the appropriate behavior in a role and rewards (or punishments) for performance may vary depending on the age of the person occupying the role. The most obvious use of age in social structures occurs when chronological age criteria are written into law, regulations, or contracts. For example, in contemporary US society, age regulates when it is legal for one to marry, drive a car, leave school, drink alcohol, vote, and become president. Further, chronological age is a criterion for receiving Medicare insurance, pension benefits, and selected tax benefits. There also are informal norms that use age to indicate what behavior is or is not acceptable, such as when one is judged as too old to become a foster parent, to enter a graduate program, or to participate in certain

sporting events. As with all norms, age norms are sometimes violated and can change over time. Nevertheless, the age stratification perspective calls attention to the importance of social definitions of age as forces that shape behavior and the aging of individuals.

The final component of the age stratification model deals with the processes by which the individuals in an age stratum are matched with the appropriate age roles in social structures. Allocation processes are used to assign people to age-appropriate roles and to continually reassign them as they age into different socially recognized phases of the life course. The mechanisms for allocating may be individuals in roles designed for this purpose (e.g., personnel managers or admission directors) or policies (e.g., pension plans or school attendance regulations).

This general phenomenon of allocation is closely related to several key theoretical ideas and research questions. For example, according to the Easterlin effect, the members of small cohorts have a broad-based advantage in that members of such cohorts will experience less competition for the finite number of age-graded roles as they enter particular age strata (e.g., admissions slots to elite colleges or choice entry-level jobs), whereas members of large cohorts will face greater competition. These differentials of advantages can carry on through the life course. In any pyramidal organizational structure (which describes not only corporations but also military, ecclesiastical, and educational organizations), the chance to be promoted to one of a few high-level managerial or executive slots will be enhanced if one has fewer competitors. On the other hand, it has also been suggested that under some conditions, individuals in an age stratum may benefit from being members of a relatively large cohort; for example, this might have applied to the male Baby Boomers who were in the draft lottery in the early 1970s. It has also been hypothesized that those retiring in the early twenty-first century may derive political advantage because they will comprise a larger relative size of the electorate.

Riley used the issue of the person–role mismatch to call for social change. She developed a critical analysis of inelastic, age-graded social arrangements that result in humanly destructive consequences. This critique led to the development of the concept of structural lag (discussed later).

The age stratification perspective also recognized that the concomitant process of socialization operates constantly, in parallel with allocation. That is, in everyday life experience, individuals are continuously internalizing the social practices and learning the skills that are integral to the roles that they occupy in the larger social system. The concept of socialization has been widely and effectively critiqued because of a number of conceptual and theoretical limitations that it imposes on the kinds of questions one would ask as a researcher. Nevertheless, the powerful processes through which individuals are shaped by the roles they occupy are a central feature of the reality that the age stratification model seeks to represent.

Age Structure and Cohort Flow

As a temporal snapshot, the age pyramid reveals virtually nothing about the actual aging of individuals. Rather, it describes the piling up at a single point in time of successive cohorts. Viewed over time, the movement of cohorts will produce shifts in the population age structure. Often, however, the age-graded role structure is relatively static, and Riley coined the term cohort flow to describe the movement of cohorts through it. As one cohort moves out of a particular age stratum, it is succeeded by another that enters that age stratum. This static–dynamic distinction highlights the dangers of the life course fallacy, which is the practice of inferring life course changes from cross-sectional age differences. This is a key point that researchers and consumers of research overlook at the peril of misleading interpretations of data. But this distinction also brings us back to the important substantive issue of strain: the dynamic movement of unevenly sized cohorts through a relative static and inelastic structure consisting of a finite number of roles is a source of strain.

Challenges and Criticisms of the Age Stratification Approach

Two basic types of criticism of Riley's formulation of the age stratification approach can be distinguished. First is a critique focusing on the lack of clarity and consistencies in its use of the concept of stratification. Second is a critique of the functionalist assumptions on which the model was built.

Age and the Concept of Stratification Influenced by the youth-driven social disruption of the 1960s, Norman Ryder recalled Mannheim's discussion of the role of generations in producing social change to elaborate the analytical importance of cohorts. Riley and her associates forged the concept of age stratification in the wake of the same set of real-world dynamics. Like the concept of cohort, the age stratification perspective turned out to have an intellectual value that was broader and more sustained than the social movements of the 1960s that initially inspired it.

Important ideas deserve critical scrutiny, and age stratification has been no exception. Using the term stratification to capture the cross-age tensions of that decade invited questions about the extent to which a homology with class or other forms of socioeconomic stratification was intended. For example, questions were raised about the choice of the term age stratification because of the important ways in which age stratification is fundamentally different from stratification in its traditional guises. Interestingly, in the past two decades new insights into aging have been gained by research that looks at the intersection of age with other bases of stratification, such as gender, race/ethnicity, and social class, utilizing concepts such as cumulative advantage.

Age Stratification and the Functionalist Perspective A second and more enduring line of critique of the age stratification perspective has focused on limitations associated with its Parsonian functionalist underpinnings. Clearly, the key strengths of the age stratification model derive from the analytical refinement and precision of the Parsonian framework, as described earlier. In particular, the person–role distinction and the conceptualization of age as a feature of social structure provide the basis for the social critique that Riley articulated as structural lag and the vision embodied in her writings of an age-integrated society. Yet critics of age stratification rightly note that serious limitations derive from its avoidance of issues of (1) power dynamics and (2) mechanisms of social change. Serious attention to these would have brought the issue of the interaction of age with other bases of stratification to the fore much sooner.

Much like Parsons, Riley dealt with the problem of reconciling human action and structure through a heavy reliance on voluntarism. Thus, Riley's discussions of how individual agency produces change in large-scale social systems focus on the aggregation of individual choices in processes such as cohort norm formation. In every case, she avoided examining the role of (1) social movements in shaping (rather than merely expressing individual aspirations), and (2) of institutional power as it operates in everyday life to organize individual opportunities, to limit choice, and indeed to shape individual taste and perception. These limitations derive directly from the underlying assumptions of consensus and voluntarism that are simultaneously hallmarks and limitations of the functionalist framework. It is thus a considerable irony that, in spite of these limiting aspects of functionalism, Riley used the analytical precision of that framework to generate a radically new and potentially liberating vision, exposing how age operates as an aspect of social systems (e.g., role structures as entirely separate from people and age as a property of social organization, value, and perception – not just of the chronological development of individuals).

Issues Related to Age Stratification

The age stratification framework has provided a basis for several critical assessments of how aging is socially constructed in modern societies. Three of these issues are discussed here.

Competition between Age Strata

The potential for competition and conflict to develop between age strata exists because each age stratum occupies a different position in the socially constructed life course. The self-interest of individuals may vary depending upon their life course location: older people may have different concerns than young people. For example, the well-being of older people in the United States in the early twenty-first century is directly affected by public pension and health-care policies, whereas the well-being of young people is directly affected by education and child-care policies. Given limited resources, one might expect competition between the old, who benefit from greater government spending on Social Security and Medicare, and the young, who benefit from greater spending on education and child care and greater tax relief for parents with young children.

A lively debate over the possible emergence of interest group politics based on age (the generational equity debate) developed after 1984, when an article by Samuel Preston in *Demography* called attention to recent trends in poverty for different age strata. The divergent trends between old and young are quite striking: between 1970 and 1995 the proportion of older people in poverty declined from 25 to 12%, while the proportion of children in poverty increased from 15 to 23%. An important reason for declining poverty among older people was the increase over this time period in government transfers to the older population. By 2000, per capita social welfare spending from all levels of government was three times larger for the population over age 65 than for the population under age 19 ($19 700 versus $6400). Some view this discrepancy in government spending on young and old, in combination with the divergent trends in poverty, as evidence that there was inequity in treatment of different age strata. Children were suffering because of excessive political power of the old, and this inequity might become even more severe as the large Baby Boom cohorts move into old age.

Despite what may appear to be a conflict of interests between young and old, empirical studies have

not found any significant age-based differences in political views among voters. Younger voters are as supportive of Social Security and Medicare as older voters, and there is no indication that voters become less supportive of local and state taxes to support public education as they grow older. There are two reasons why a polarization between age strata may not occur despite the forces that could push in that direction. First, in contrast to the relatively fixed statuses of sex, race, and even social class, upward age mobility is inevitable (unless one dies). Because younger adults anticipate moving into old age in the future, efforts to reduce the benefits going to the old would work against their own long-term interests. Second, many non-old adults either have parents or will have parents who are old. The large government transfers to the old are a major reason why few older people are dependent upon adult children for economic support. Thus, the collective strategy to keep older people economically independent serves to protect the assets of middle-aged adults. In fact, the current arrangement results in many older adults being able to transfer resources to their children and grandchildren. It is not clear, of course, how the possibility of age conflict in the future will play out, but recent history has been marked primarily by intergenerational support.

Structural Lag

A starting place for thinking about structural lag is the distinction between age as a property of individuals and age as a property of social systems. At any time, a given birth cohort will comprise that collection of individuals occupying a particular age stratum (e.g., 65–69). Because cohorts of varying size and composition are constantly moving through role structures that are relatively stable, it is always possible for a mismatch to exist between the capacities of the individuals in an age stratum and the places available for these individuals in social structures. This is especially likely when age is objectified as a property of the social system through various forms of age grading – making age a legal or normative criterion for role access. When such a mismatch develops in a particular historical context, it may be described as a structural lag. That is, social change has not occurred in a way that is congruent with changes in the aging of cohorts.

Why might an asymmetry develop between structures and lives? Although changes in patterns of aging and changes in social structures can affect each other, each process follows its own dynamics. The capacities of a cohort at a particular age are shaped by its past experience of aging through a unique slice of history, for example, the health and educational environment when the cohort passed through childhood, or the work opportunities and family norms existing as it moved through early adulthood. Social structures, with their age-graded roles, however, do not follow any rhythm analogous to human aging but are affected by political, economic, and social developments. Thus, the qualifications, expectations, or needs of individuals in a particular age stratum may not be compatible with the available places in social structures.

The most noted example of structural lag at this time involves the failure of social structure to accommodate the needs and interests of cohorts entering old age. Because of historical changes, people entering old age in recent years are healthier, better educated, and expected to live longer than the members of cohorts that preceded them. But in many advanced societies of the twentieth century, social structures imposed more restrictions on opportunities for older people to be productive than existed before the advance of modernity. For example, work organizations do not provide an adequate number of jobs with the flexible working conditions that would match the needs of older workers. Similarly, educational opportunities and volunteer opportunities for older people lag behind the needs of the resourceful people entering old age. Ways in which the lives of older people may lag behind structural changes can also be noted. Because opportunities and incentives for lifelong learning have been lacking, members of cohorts entering old age may not be equipped to participate in structures requiring new technological skills.

When structural change lags behind changed lives, or when lives lag behind structural changes, pressure for change may develop. Such changes do not come about randomly. They may result from scientific progress that leads to demographic change or complex cultural shifts that lead individuals to change their aspirations. When such initiatives lead to wide-scale change in values and perceptions, the result is cohort norm formation (discussed previously). A prime example is the impact of the women's movement of the late twentieth century on the life course aspirations of young and midlife women. Similarly, the media shape the thinking of elders, as well as nonelders, about the situation of older people. The media sustain ageist stereotypes, but also provide information about age discrimination and increasingly provide positive images of old age, especially as commercials target this growing demographic segment of the population. Organizations of senior citizens may lobby for the interests of older people. Policy makers in government and the private sector may recognize

areas of structural lag and initiate changes to reduce the mismatch between individuals and roles. It is also possible, however, that structural lags could persist and trigger conflict across age strata.

Age Segregation

Age stratification leads directly to the possibility for age segregation in a society. The existence of age segregation can be studied both at the structural level and at the individual level. There is extensive empirical evidence that a high degree of age segregation currently exists at both levels.

Age segregation at the structural level can be seen by the use of age as an eligibility criterion for participation in social activities. The clearest examples of age being used to direct people to enter or leave social structures are seen in the social institutions of education, work, and retirement. At a fixed chronological age, children are expected to enter a graded school system, and then, if 'normal,' to move lockstep with age peers through the system. Young adults are expected to finish school and move into work settings that exclude both the young and the old. Finally, as old age approaches and opportunities for participating in school and work sites are limited, adults are expected to move into the last phase of life – retirement.

Socially created separations between age groups are exacerbated by rules and practices in other institutions as well. Age criteria are used to control access to health-care institutions and welfare programs. Religious congregations frequently structure activities on the basis of age, sending children, youth, young adults, and older adults into separate programs. A pattern of residential segregation by age can also be seen, as is obvious in retirement communities and college dormitories.

At the individual level, age segregation occurs when there is an absence of social interaction between people of diverse ages. Studies of personal social networks reveal that very limited cross-age interaction occurs in modern society, particularly among nonkin. The linkage between age segregation of social institutions and the age segregation of personal social networks is straightforward. Institutional age segregation restricts the age range in the pool of persons from whom network members are typically recruited. Similarly, the lack of social interaction between individuals of diverse ages allows the perpetuation of age stereotypes that are then used to justify institutional age segregation.

Moving toward a more age-integrated society could potentially benefit people of all ages. First, through social interaction, older and younger people could provide mutually beneficial socialization. As Margaret Mead once argued, in a rapidly changing society in which youth have a greater mastery of new technology, the old need the young to be their teachers if they are to avoid becoming marginalized. It is also the case, however, that youth benefit from learning history from older people who have relevant life experiences. Second, through interaction, older and younger people can develop empathy for the challenges faced by those in different life course positions. This understanding offers an opportunity for reducing age stereotypes and for breaking the mutually reinforcing cycle of ageism and age segregation. Third, relaxing rigid age boundaries would allow individuals at all stages of life to more easily move between activities related to education, work, and leisure. Encouraging older people to engage in productive activities could lessen the burden of their dependency on younger adults, and allowing more diverse opportunities for younger adults could reduce the role overload associated with this phase of life.

In considering the possibility of reducing age segregation, it is important to recognize that human aging is alterable. The age-segregated life course that emerged in recent history was produced by social institutions that were constructed in particular ways. This suggests that changing these institutions could produce increasing age integration. And there are signs that structural barriers to age integration have abated in recent decades. Examples of recent changes encouraging greater age integration can be found in education, where lifelong education is receiving greater attention, and in work, where there is increasing job flexibility and increasing use of incentives to encourage working later in life. There is no reason to doubt that the aging experience of cohorts entering old age in coming decades will differ from that of the cohorts who preceded them. Whether or not this will bring about increasing age integration is an important but open question.

Conclusion

Age stratification is a model of aging that has profoundly affected how social scientists understand the process of aging and the meaning of age in society. It recognizes that although chronological aging is inevitable, the way in which individuals age from birth to death depends upon social organization and the social practices that derive from an individual's location in social structure. As the forces associated with modernity have transformed societies, the legal-bureaucratic use of age as an eligibility criterion has increased. The emergence of age norms that govern many aspects of life, the institutionalization of the

life course, gives social meaning to age and gives direction to how people 'ought to' age. There is no reason to assume, however, that the normative age-graded life course that shapes how individuals age in the early twenty-first century is either necessary or beneficial to human beings. The age stratification perspective addresses this issue because, in addition to providing a framework for examining how aging is socially constructed, it provides a basis for critically examining the human consequences of structuring age in particular ways.

See also: Ageism and Discrimination; Demography; Generational Differences: Age-Period-Cohort; Life Course; Network Analysis.

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Ageism and Discrimination

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Glossary

Ageism – Prejudice, discrimination, and stereotyping against someone based on his or her age.

Implicit Stereotyping – When a perceiver evaluates a member of an outgroup without realizing the influence of automatically activated stereotypes about the outgroup.

Terror Management Theory (TMT) – A theory suggesting culture and religion are creations of humans that put order and meaning on the world. Self esteem comes from the thought that our being in this world has a purpose. Fear of aging becomes a fear of having no purpose.

Introduction

Ageism refers to prejudice, discrimination, and stereotyping against someone based on his or her age. While it can refer to prejudice against younger persons, ageism, as the term is used by most researchers, typically refers to prejudice against older persons. Over the centuries, the nature of various societies has changed such that elders in a community have been displaced from a position of high status, commanding

respect, power, and deference, to a position of virtually no power, commanding little respect. The purpose of this article is to explore those changes, describe how ageism is manifest in the lives of its targets, and how those targets react to such treatment. Ageist behavior and ways to reduce ageism are also discussed.

Origins of Ageism

Historical Changes

In agrarian and pre-industrial societies, older people were held in high regard. They typically wielded the most political and economic power in their communities. Elders were valued for their life experience, wisdom, and knowledge of the history of their community. Older persons were the historians and libraries of their communities, so to speak. Those who wished to learn about the nature of their society or the workings of the world would need to consult an elder for that information. As a result of their great life experiences and their knowledge about their community history, older persons were the leaders of their communities. During this time, older persons were revered, respected, and admired by their community for their leadership, wisdom, and life experiences.

Three major developments heralded a major change in the way that younger adults viewed older adults. The first was the development of the printing press. A large part of the status that elders had in their societies derived from the fact that their lifetime of knowledge, information, and memories about the history of their community and the world beyond was far beyond that of others in their community. They had knowledge and expertise that no one else had. They represented an almost oracle-like, one-stop shop for the community members who desired to learn more about virtually anything they needed to know to survive and thrive in their community. However, the advent of the printing press meant that such information was no longer the sole province of the elders; instead, anyone could own that information. Moreover, in much the same way that the Internet brought the world closer together, the printing press at its inception brought information from all over the world to small, heretofore isolated communities.

The second major development was the industrial revolution. Prior to that period, it was quite common for a typical family structure to be extended in that grandparents would live with their children and grandchildren in the same house. Elders were revered, were respected for their wisdom and knowledge, and were valuable educators to their children and grandchildren. The industrial revolution created a boom in employment that resulted in the need for greater mobility, so that families could move to where the jobs were located. Smaller families were more mobile. Coinciding with this change in society was a change in the way that society regarded tradition. Attitudes toward elders changed in that the moral authority of older adults to dictate what happens to their extended family (by dint of their land ownership, financial, or other political power) was replaced with ideals encapsulated in the American and French revolutions. The idea that all men are created equal and all are on the same footing for their own families' welfare took a strong hold in the hearts and minds of Europeans and Americans. Moreover, the industrial revolution emphasized a value on innovation, rather than tradition. To be successful and thrive in this new world, young people needed to value new, creative ideas, and because older people represented tradition and were seen as unwilling or unable to adapt to new, creative ways of doing things, older people were devalued and even seen as an obstacle to the success of younger persons. Forced retirement was created as a way to legitimize this increasing bias in favor of the young, so that after a worker reached a certain age, he or she was no longer a part of the workforce.

This period heralded great advances in medicine, which was the third major historical factor that led to the rise in prejudice against older persons. In pre-revolutionary America, only about 2% of the population lived beyond age 60. As medicine allowed people to live longer, however, society and families were faced with finding a place and a role for older people in society. Unfortunately, with the diminished status and power of older adults in society, the rights and welfare of older adults were often regarded as unimportant. Younger adults tended to not want the burden of dealing with older adults and their health concerns or the financial and time demands of caring for their older family member. Older people were seen no longer as sage teachers, but as non-productive relics of a bygone era who should be marginalized to the fringes of society. If younger adults did not want their elderly parents living with them, preferring that someone else manage their parents' care, a place such as a nursing home could fill that need. Indeed, nursing homes have grown in popularity in the United States ever since President Roosevelt signed the Social Security Act in 1935. It should be noted that prior to that time, most states did not have nursing homes, but rather alms houses (sometimes known as poor farms) where poor older adults were sent. They had inadequate facilities, and older adults there were treated miserably. States encouraged the stigma regarding these houses in an effort to

discourage people from relying on them. Though today's nursing homes are vast improvements from these earlier institutions, there is a definite stigma that surrounds nursing homes, in terms of how older people regard them and how society regards older people living in them.

Theoretical Perspectives

Terror Management Theory An interesting theory that has been put forth to account for the origin of ageism is terror management theory (TMT). TMT suggests that culture and religion are creations of humans that put order and meaning on the world, and this keeps at bay the scary thought from childhood that the world is chaotic and random. According to TMT, we derive our self-esteem from the thought that our being in this world has a purpose. The fear of aging then becomes a fear of having no purpose (i.e., when one retires from a job). Since older people are a reminder to the young of their mortality, older people become a salient symbol of a feared future self. Experiments have shown that people deny the reality of their mortality by denigrating and stereotyping older people as bringing about their diminished or lower-status situation onto themselves. People fool themselves into believing that such a fate will not befall them. Research on the theory has shown consistently that when people are reminded of their mortality, they are more likely to stereotype others (as a way of enhancing their self-esteem and thereby denying anxiety of their own mortality).

Researchers studying TMT have argued that because death anxiety is so powerful in the United States, the TMT effects on prejudice and stereotyping of older adults are unlikely to diminish unless a concerted effort is made to educate the public about death. If death is demystified, reframed as a natural part of the life cycle, and generally normalized, perhaps anxiety about death (and about people, such as older adults, who are reminders of mortality), will diminish. When that happens, even though older people will always remind the young about their mortality, they may be less likely to evoke anxiety in younger people, who then may be less likely to stereotype older adults.

Ambivalent Attitudes Toward Older Adults Decades ago, research indicated mixed evidence for the existence of ageism. Some studies suggested that people had very positive attitudes toward older adults, while others suggested that society regarded elders in a negative light. Upon closer inspection of the research methods in these studies, it is clear why this discrepancy exists. Studies that yielded positive attitudes toward elders tended to ask about attitudes toward specific older adults in the respondent's life, such as his or her boss or grandparent. In those cases, the personal relationship is likely what dominates the person's attitude toward the older adult, and that may be the basis upon which the respondent answers the question. However, when people are asked about their attitudes about older people in general, their responses are often much more negative. Over the decades, then, much research has confirmed that, indeed, there is a pervasive, negative view of aging and, by association, older adults. These negative attitudes give birth to stereotypes and prejudice about elders.

Recent research indicates that older adults are regarded by younger people as incompetent but warm. In other words, older adults are viewed as having little to offer or contribute to society, but they are valued almost on a sentimental level for what they represent (values, tradition, family). The dependent relationship that often emerges between elders and their adult children often contributes to the tendency to treat elders as though they were childlike. Younger people tend to not want to discuss complicated, serious matters with their elderly parents, fearing that such topics will either be too upsetting or too sophisticated or intellectual for the older person. The insidious nature of this stereotype (i.e., that older people are like children) is that it influences the beliefs and behavior of the older adults about themselves. Many start to buy into this stereotype and foster the dependent relationship by acting in ways that they are expected to act, according to society's age grading and stereotypes held by younger persons (this point is discussed later in the section on experiencing ageism).

Implicit Ageism In recent years, researchers have discovered that overlearned links between people and characteristics in our memories can have significant effects on the way we think, feel, and behave toward those people. Specifically, strong stereotypes about a group will lead a person to be especially likely to automatically think about members of that group in terms of those stereotypes. When the individual is aware of the fact that he or she is stereotyping the person he or she is thinking about, that process is referred to as stereotyping (or prejudice, or, if the person is acting negatively toward the stereotyped target, discrimination). However, when the perceiver is unaware of the influence of the automatically activated stereotypes about the outgroup when he or she is evaluating a member of the outgroup, that process is referred to as implicit

stereotyping. Implicit stereotyping is all the more difficult (but not impossible) to control and remedy because the perceiver is unaware of its activation and influence.

Implicit ageism originates when children learn, from a very young age, that older people are not highly regarded in society. Research on children's books, school books, and fairy tales shows that these books are highly biased against older people. Older people are rarely featured in books for children, and when they are, it is usually as problem creators or dependent characters. One study found that the portrayal of older persons in children's books mirrors the ambivalence of society toward elders, in that the older characters were most often described as poor, sad, wise, and dear. These stereotypes, conveyed in innumerable ways from various sources throughout a person's life, become quite strongly associated with older persons, to the point that the mere mention or perception of an older person automatically evokes those stereotypes, often outside of conscious awareness. Implicit ageism can be unlearned, but research shows that doing so requires a tremendous commitment of motivation and effort to recraft default concepts about elders and to break the association between negative characteristics and the category of older adults. This is discussed further in the reducing ageism section.

Variations of Ageism

Ageism in Health-Care Professionals

Surprisingly, ageism is also found among those whose careers revolve around promoting the physical and mental health of others. For example, one study of medical students' recommendations concerning breast-conserving strategies found that medical students were significantly more likely to recommend breast conservation procedures for younger (86%) than older women (66%). Those students were also significantly more likely to recommend mastectomy for older patients (95%) than for younger patients (65%). The authors of the study suggest that, given the similarity in diagnosis, the difference in treatment recommendations reflects a clear ageist attitude on the part of the medical students. Other researchers have written extensively about the implicit (and sometimes explicit) ageist attitudes that are communicated to med students (and which med students then internalize). For example, some physicians tend to view older adults as lonely, depressed, or inflexible. Some physicians regard treating older adults as an exercise in futility, given the cognitive and physical limitations of elders. In other words, some regard treating the health issues of older adults as less important than treating the same medical conditions in young persons. As a result, physicians may be much less likely to prescribe aggressive medical interventions to alleviate the problem of older adults and are more likely to prescribe medicine to help older adults manage their pain.

Among mental health professionals, ageism is also frequently in evidence. Some therapists are reluctant to treat older adults, due to their misconceptions and stereotypes about older adults as merely lonely people in need of someone with whom they can talk. Some stereotype older clients as grumpy, suspicious of psychology, too talkative, or non-talkative. It may also be the case that these stereotypes are fueled by a healthism, or a stereotype about people who are in poor physical health. That is, some therapists are more likely to rate the psychological prognosis of older clients less optimistically compared to younger clients with the same presenting concerns.

Communication of Ageism

Based on their stereotypes of elders as dependent, and childlike, younger people tend to communicate with older adults in a negative fashion. One type of communication is termed overaccommodation; it describes the situation in which a younger person is overly polite, exaggerates his or her intonation, speaks louder, and speaks in simple sentences when talking to an older adult. Another type of negative communication has been termed baby talk; this refers to an exaggerated intonation, high pitch, and, sometimes, non-words or baby-speak that one would use when talking to a baby. Research indicates that older people differ in how they react to such communications. Those older persons who are higher in social, physical, and cognitive functioning find such speech degrading and insulting. However, those who are lower in those capabilities tend to actually prefer such speech, because it seems to communicate a secure, nurturing quality in the speaker, which the older person (who needs someone to attend to his or her needs) finds comforting. Younger people have also been shown to communicate their ageist assumptions via the way they interact with older adults. If younger people believe that elders are childlike, they will be less likely to treat the opinions of older adults seriously and will tend to restrict their conversations with elders to simple, pleasant topics.

Institutionalized Ageism

One of the major reasons why research on ageism lags far behind the volume of empirical interest

generated by racism and sexism is the institutionalized nature of ageism. That is, age prejudice is so pervasive throughout society, that virtually everyone knows about the stereotypes, and yet few regard the stereotypes as on the same par as prejudice based on sex or race. In other words, most people do not recognize age prejudice within themselves or in others. Of course, if people do not recognize ageism, reducing or eliminating it becomes that much more difficult.

That American culture is youth-oriented is not news. There is a multibillion dollar industry built around promoting products that help people conceal signs of age (antiwrinkle and age spot removal creams, wigs, etc.). Cosmetic plastic surgeries have increased in popularity over the last two decades. Advertisers cater their marketing to what they believe is their most desired demographic (those most likely to spend money on the sponsors' products), those who are 18–40 years old. Indeed, it is strange that advertisers do not specifically focus on those with even more disposable income: older adults aged 40 to 65 (those older than 65 may be restricted by a fixed income from Social Security, pensions, etc.). These older adults are more likely to be financially secure and are more likely to have money to spend on themselves and on products for their loved ones. Older adults are portrayed in television shows and movies as forgetful, grumpy (or mean), asexual, and silly and are frequently the punch lines of jokes made by younger persons. Due to the age grading of society, in which there are implicitly understood acceptable behaviors for people depending on their age, when older people engage in an interest or behavior that is age-inconsistent, they are regarded as cute or silly (e.g., skiing or running) or repulsive (e.g., having sex). Here again, stereotypes about aging needlessly restrict people's beliefs about what behaviors people can do and what interests they may have at various ages throughout their life.

One obvious example of the extent to which ageism is institutionalized in American society can be found in the greeting card industry. The prevailing message in the vast majority of birthday cards is a joke about how sad it is that the card recipient is another year older. Cards make fun of the recipient's age by pointing out (as indisputable fact) the recipient's deteriorating health, loss of worth or lessening contributions to society, and failing memory. A cottage industry has been built around the phrase over the hill, with black balloons, mock tombstones, hearing aids, and other ageist items available to purchase for the individual having the birthday. The public at large regards such messages and jokes as a harmless stretching of the truth.

Experiencing Ageism

The influence of age prejudice, stereotypes, and discrimination on the well-being of older persons is a topic that remains largely open for empirical inquiry. Like most research in prejudice, the examination of the influence of prejudice on the target of prejudice has only recently gained empirical and theoretical attention.

Treating older adults like they are children communicates the presumption of a dependent relationship of the older individual, and it can lead to self-fulfilling effects, in that the older adult may start to believe the validity of the stereotypes being communicated in the behavior and language of the younger person. Research has demonstrated that older people who start to believe stereotypes about aging tend to behave, think, and feel according to those stereotypes. This can have significant implications for their overall physical health. One study found that older adults with a more positive self-concept actually lived 7.5 years longer, on average, than their low self-concept counterparts. Older people who act according to stereotypes about older adults are regarded by other older people as less alert, helpless, and weak. A plausible explanation for this result is that it is due to a black sheep effect, predicted by social identity theory, which suggests that if a stereotyped group has a member acting in stereotype-consistent ways, he or she will be shunned by other group members, because that individual's behavior is tarnishing the group's efforts to overcome stereotypes about the group.

A useful distinction between two groups of older adults has been made in the research literature. Those who are between the ages of 55 and 74 are referred to as the young-old, and those 75 and older are referred to as the old-old. This distinction reflects the fact that most negative stereotypes about older adults tend to derive from assumptions about or distortions of characteristics sometimes found in those older than 75. When applied to those young-old persons, the mismatch between stereotype and reality is likely to be even greater. One recent survey of more than 850 older adults in California asked older participants to indicate whether they had ever been the victim of ageism, and if so, how they felt about and reacted to that treatment. Responses provided further support for the conceptual distinction between the young-old and the old-old. Those respondents who were 74 or younger indicated that yes, they had been the victim of ageism, and when it did happen (and each time it happened), they became angry. Those respondents 75 or older were significantly less likely to indicate that they had ever experienced

ageism, and saying that if and when it did happen to them, the ageist treatment did not bother them. The young-old in this survey became angry when stereotypes about elderly people (not them!) were applied to them. The old-old seemed to accept the validity of stereotypes about older people (i.e., themselves), and did not feel offended when those stereotypes were applied to them. Some researchers have speculated that the reason people in stigmatized groups are unwilling to acknowledge the prejudice against either their group or themselves personally is that if they did admit such treatment, the thought would be too unsettling or anxiety provoking for them. Specifically, the thought that no matter what one does, he or she will be regarded negatively by others due to his or her membership in a stigmatized group is discouraging, to say the least. Some research evidence supports this interpretation of findings such as these, but much more empirical attention is needed to be more confident in this explanation.

Though indirect, another way that older adults experience the negative attitudes of society about aging is through retirement. Voluntarily leaving the workforce, of course, usually does not carry with it negative experiences of ageist attitudes, compared to situations in which the employee is forced to retire or retirement in that position is mandatory. In these latter contexts, the older adult has a more difficult time transitioning to postwork life. These individuals struggle with the message that they have received from their forced retirement, that even though they may be capable and experienced, society still does not want their contributions. Much research supports a basic tenet of social identity theory that says that much of people's self-concept is rooted in their occupation. We are what we do. When an older person retires, that major part of his or her self-concept is no longer there, and the individual must find new ways to define him- or herself. That transition is a difficult one, even under the best of circumstances. However, it is especially problematic if the person was forced to retire.

Another problem with postretirement life is that American society has not thoughtfully considered and provided clear roles and opportunities for elders who still wish to contribute their expertise and wisdom to their communities (via the workforce, education, or other avenues). People have a strong need to feel that they are needed and that their contribution to their community is important. The culture at large, and communities in particular, need to pay more attention to making the postwork life of older adults a more community-connected, meaningful, enjoyable, and satisfying time of their life.

Workplace Discrimination against Older Persons

One of the most common types of discrimination against older persons is workplace discrimination. Employers tend to be unwilling to acknowledge age discrimination practices at their company, or they may be unaware that those practices constitute age discrimination. In one study, when employers were confronted with their company's lack of older workers in certain positions, they explained that age disparity as due to something about the older workers themselves (i.e., that older persons do not want that type of position) or due to external factors (population trends, dearth of older workers with job-specific skills, etc.).

When the work performances of older and younger workers are evaluated, it is found that older workers tend to receive more severe evaluations if they have performed poorly. Older workers who get poor job evaluations are less likely to be referred to remedial training than their young counterparts. This may be due to ageist beliefs about the ease with which older people can learn new information. The more ageist beliefs the employer endorsed, the more likely he or she was to call for the poor-performing older person to be fired (compared to the poor-performing younger worker). One study found that when older workers link their identity with the characteristics of their same-age peers, their self-esteem is reduced, and they feel a greater sense of relative deprivation when they compare their outcomes with those of younger workers.

Moreover, experiencing workplace discrimination influences people's well-being in retirement, in that those persons are less satisfied with their lives. Being an early retiree has its downside in another respect: these individuals feel like they are too old to rejoin the workplace, yet too young to join groups of retirees or senior citizens. Thus, they have a more difficult time navigating where they fit in the post-workplace world, and society has done little to accommodate such workers.

Ageism across Cultures

Ageism is not a universal phenomenon. There is great variability across cultures, and even within some cultures, in how older adults are treated. Some researchers suggest that the ageism of the United States represents a subtle form of abandonment. This has the ring of truth when considering policies such as forced retirement and the lack of attention that America gives to postretirement life. Not only are elders psychologically abandoned or forgotten, but also the message is communicated that when people

get old, they should not be a burden to their family, and thus, they ought to go to a retirement home, nursing home, or other facility. These messages tell older adults that they are not needed or valued and should stay out of the way of the younger adults.

Not all societies are as ageist as the United States. Traditionally, Eastern cultures are very reverent toward their elders. Much of this attitude is rooted in how these cultures view death. In contrast to the United States, Eastern cultures view life, death, and the self as intertwined. Death is seen as a welcome relief from the suffering of life, and as a way of joining one's revered ancestors. Interestingly, recent research shows that as Eastern cultures become more Westernized (adopting capitalist, democratic, market-driven economies and valuing individual freedoms and pursuits), their attitudes toward older adults have become more negative. The degree to which the values of cultures change from emphasizing tradition and experience to valuing change and innovation will influence how those cultures treat their elders. As TMT rightly shows, the strong fear of death is a powerful contributing force to ageist behavior, age prejudice, and age stereotypes.

Reducing Ageism

In order for discrimination, stereotypes, and prejudice against older adults to be reduced or eliminated, fundamental changes in the way society views aging need to occur. Researchers agree that if society enacts the following 10 changes, there will be a significant impact in reducing and eliminating ageism in the United States.

1. Information needs to be shared with media outlets and authors (notably of children's schoolbooks and entertainment books) that older adults have a great deal to contribute to other people and society.
2. Opportunities for older adults to contribute to their community should be created.
3. Conditions need to be created that allow older adults more control and independence in their lives.
4. Much more attention needs to be given to postwork life for older citizens. Their lives can be fulfilled with continuing opportunities to contribute, and they can grow and thrive mentally, socially, financially, and emotionally.
5. Contact between older adults and younger people (including, of course, children) should be increased and encouraged, so that children and young adults are exposed to the wisdom, history, and value of interacting with adults with so much experience. Doing this demystifies what older people are like, and it helps break down the stereotypes about older adults.
6. Stereotypes and myths about aging need to be confronted with actual figures and facts about aging.
7. Perspective taking should be used as an effective method for teaching empathy for other groups; some evidence suggests this is effective in significantly reducing ageism.
8. The way that society views death (currently with dread) needs to be directly confronted, such that death is reframed as a natural part of the life cycle that is not to be feared, but accepted as a normal part of life.
9. Efforts need to be made to address all explicit and implicit institutionalized ageist practices and traditions (e.g., hiding signs of aging, jokes about negative characteristics about older people).
10. Younger people need to be taught that older people should be treated with respect.

Over the last several decades and continuing to the present, much more empirical and theoretical attention has been devoted to understanding other types of prejudice. Little attention, however, has been devoted to understanding age prejudice. As a result, our understanding of the causes, maintaining factors, and consequences of ageism is nascent. Ageist beliefs and behaviors are so entrenched in American culture that they have become institutionalized; this may be a likely reason why researchers have not devoted much attention to the problem, and why everyday citizens do not perceive age stereotypes or ageist practices as a problem. The US Bureau of the Census projects that the number of people over age 65 will double by the year 2030. This graying of America represents a major change in the complexion of the demographic of the country, and with it will come a major demand on society's resources (economic, health, legal) that, at present, it is ill-equipped to handle. It is crucial that we devote much more research attention to understanding and eliminating ageism. In so doing, we can help policymakers, researchers, educators, and society at large make the changes needed to significantly enhance the quality of life for all older adults in society.

See also: Age Stratification; History of Aging; Retirement; Work and Employment: Individual.

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Alcohol and Drugs

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Glossary

Alcohol-Related Problems – Medical, legal, occupational, family, and social problems.

Illegal or Controlled Substance – Schedule I drugs, defined as manifesting a high potential for abuse and no currently acceptable medical use, including heroin, LSD, and marijuana.

Medications – Any drug substance, prescribed or over-the-counter, taken for therapeutic purposes. This includes prescribed use of psychoactive drugs.

Pharmacodynamics – Physiological and psychological response to drugs; there are gerontological changes in drug response.

Pharmacokinetics – The time course of absorption, tissue distribution, metabolism, and excretion of drugs and their metabolites from the body.

Introduction

A drug is defined as any substance (not food), natural or synthetic, which by its chemical nature alters an organism's structure or function. Drugs may be found in nature or they may be produced in the laboratory. They may also be classified in terms of their chemical composition or, in the case of psychoactive drugs (e.g., alcohol, opiates, nicotine, etc.), in terms of their central nervous system action. A major classification is in terms of social acceptability; drugs vary from widely accepted (caffeine) to illicit substances, which often appear as 'street drugs' (heroin). Drug abuse and drug dependence may be defined as deviant usage. Diagnosis is usually made in terms of the American Psychiatric Association standards set forth in the *Diagnostic and Statistical Manual IV*.

There are several classes of drugs to be reviewed here. First, there is the use by older people of medications in general and psychoactive medications (anxiolytics, stimulants, etc.) in particular; there are likely to be prescribed, although there is a 'street' supply from non-medical sources. Second, there is the use of over-the-counter (OTC) drugs that need no prescription and may be bought in any pharmacy. Third, there is nicotine used by Americans of all age groups and by the elderly. Fourth, are the controlled

substances, banned by law. The best known controlled substances are marijuana, heroin, and cocaine; associated with crime and violence, these drugs get the most media attention. Fifth, there is the use and abuse of the legal drug, alcohol.

A major area of study is the biological change over the life span that occurs in the body's response to different drugs. Pharmacokinetics involves the study of the time course of absorption, tissue distribution, metabolism and excretion of drugs and their metabolites from the body, and the relationship of drug disposition to the duration and intensity of drug effects. Studying the effects of age on pharmacokinetics produces information about the mechanism of altered pharmacodynamics in the elderly. Pharmacodynamics is the physiological and psychological response to drugs. Pharmacodynamics is concerned with the greater or lesser response of older people to particular drugs, independent of pharmacokinetic effects. Different psychoactive drugs, for example, may produce different pharmacodynamic effects in the elderly (e.g., the response of older persons to some of the benzodiazepines appears to be an enhanced response).

Age Changes

Pharmacokinetics Although there do not appear to be significant age changes in drug absorption, with aging there are changes in body composition that influence drug distribution. There are age changes in drug elimination, particularly a decline in renal function.

Pharmacodynamics Age changes in sensitivity to some drugs and increased sensitivity to drugs acting on the central nervous system (CNS) are observed; the susceptibility to adverse drug reactions appears to be increased.

Adverse Drug Reactions Adverse drug reactions (ADRs) in the elderly can result from multiple drug therapy, drug overuse or misuse, slowing of drug metabolism or elimination, or to age-related chronic diseases, alcohol intake, and food–drug incompatibilities. ADRs in the elderly are more severe than among younger patients. Risk factors include being female, living alone, multiple diseases, multiple drug intake, and poor nutritional status (*see* Pharmacology).

Medications

The increase in acute and chronic illnesses that appears in older populations produces greater health-care expenditure and more medications for this subgroup of the population. Older people constitute approximately 12% of the general population, but estimates are that they receive a third of all prescriptions. Older people also buy and use a disproportionately larger number of OTC drugs. A list of the most widely used prescribed drugs includes general medications and psychoactive drugs; cardiovascular medication, diuretics, antibiotics, and analgesics are among the most frequently used drugs as are psychoactive drugs, such as sedative-hypnotics including benzodiazepines, and psychotherapeutic drugs, which include antidepressants and stimulants.

Although some treatment facilities report sizable patient intake of older persons with drug-associated problems and dependence on psychoactive drugs, this issue has never evoked much interest. It may well be that in the minds of legislators and the public, keeping older people sedated is an acceptable idea. Older persons frequently associated their intake of psychoactive drugs with problems like insomnia or depression, and almost half of those taking such drugs report that they could not perform their daily activities without the medication. The issue of prescribed psychoactive drug use and misuse among the elderly is complex and has psychological, societal, and policy components.

There are several questions related to the use of prescribed psychoactive medication. Nursing home use of such drugs is a problem, and it is questioned whether such medication is used for the benefit of the patients or for the benefit of staff to facilitate patient caregiving. Age differences in drug problems are reflected in the contrast of drug-associated emergency room (ER) use: younger patients are likely to present in ERs with emergencies relating to controlled substances like cocaine; older persons are more likely to present in ERs with problems associated with misuse of a psychoactive drug, usually prescribed. There are also gender differences. Up to age 65, women are prescribed and use more psychoactive drugs. From age 65 on, the differences become complicated, and data suggest that antidepressants are more widely prescribed for older men than for older women. This may be related to older men's utilization of medical resources, or possibility to a gender difference in psychiatric problems among older people. For older (white) men, the decline in power with aging is reflected in suicide rates. Although suicide rates remain low and stable with aging women, they rise with age among older men.

National surveys of elderly persons living in the community show a widespread usage of psychoactive drugs, and it has been noted by several investigators that older people receive a disproportionately high percentage of psychoactive drug prescriptions. The

question of abuse, misuse, and dependence is raised infrequently, usually as a caveat that a given drug (e.g., a sedative) should not be used continually for more than 2 weeks. In spite of that caution, approximately half the older persons queried in research studies report that they could not perform their regular daily activities without the medication. Societal concerns about older persons' use of substances seem to focus on alcohol.

The elderly have more health problems than younger people and therefore are more likely to be taking multiple prescriptions. Such multiple drug therapy means an increased risk of adverse drug reactions. Studies involving hospital patient monitoring have suggested a number of drugs of concern: dioxin, diuretics, aspirin, psychotropics, cytotoxins, and nonsteroidal anti-inflammatory drugs (NSAIDs). Adverse drug reactions may be a consequence of multiple drug therapy, drug interactions, changes in older persons' drug metabolism or elimination, noncompliance with prescribed drug use, incompatible food–drug combinations, or alcohol intake combined with medication use. It is estimated that the incidence of adverse drug reactions is two to three times more frequent among the elderly than among younger patients. To compound the difficulties, adverse drug reactions among older people are more severe, and there are those investigators who believe that drugs should be prescribed at lower initial doses for older patients. There are also investigators who believe that medications are over prescribed for the elderly and that some restraint in prescription would be helpful.

Data from the Drug Abuse Warning Network (reports from urban ERs) indicate that older people are most likely to present with problems relating to nonbarbiturate sedatives, tranquilizers, barbiturate sedatives, and antidepressants. On all of these, the percentage of women appearing in ERs is greater than the percentage of men.

Several classifications have been made of different usage of psychoactive drugs. One such classification distinguishes appropriate use, unintentional misuse, and purposeful misuse. Another differentiation is of benzodiazepine use: first, there is a low or therapeutic dose, the usual prescription pattern, and no withdrawal symptomatology when use ceases. There is also high-dose therapeutic use, which is again prescribed but usually produces withdrawal symptom when use ceases. Second, there is intake involved in multiple-drug use, frequently involving alcohol; here the aim is to achieve a "high" or some form of self-prescribed relief.

A problem relating to medical practice and prescription drugs is the question of non-compliance. Non-compliance is seen as a major problem, including the following:

1. Non-use: not obtaining the prescribed drug, perhaps because of cost.
2. Partial use: ceasing before course is complete, perhaps because of side effects, or combinations of prescribed drug with OTC drug not prescribed.
3. Incorrect dosage: more or less than prescribed.
4. Improper timing or sequencing of medication.
5. Shared medications.

A survey by the largest organization of older persons, the American Association of Retired Persons (AARP), found that 40% of the respondents experienced side effects; half of those said that side effects had not been discussed by health-care personnel. Although non-compliance is often attributed to cognitive limitations of older persons, a question has been raised as to whether the non-compliance is more likely to be linked to limited financial resources, a denial mechanism, issues of autonomy, and the quality of communication between patient and physician. Although it has been suggested that older people have the 'right' to make decisions about their drug intake, the extended life expectancy is related to pharmaceutical advances. What is needed is a balanced view in which patient and physician can arrive at a modus operandi and a rationale for medication intake.

Over-the-Counter Drugs

The most commonly used non-prescription drugs are analgesics, nutritional supplements like vitamins, laxatives, and antacids. Non-narcotic analgesics are the most commonly reported drugs of purchase by older persons both in the United States and in other countries. When the question is raised whether the elderly use more OTC medications than other age groups, there is disagreement. Some investigators believe that older people purchase and use disproportionately more OTC medication than other age groups; other investigators believe that elderly people do not use such OTC medications excessively.

The Food and Drug Administration has suggested that there be special labeling on prescribed drugs for persons over 65. The general response to the suggestion of special age-related labeling on OTC drugs has been negative, and consensus among investigators is that labeling by specific medical condition is preferable. It is of interest to note that more information is available to OTC drug consumers on packaging and package inserts than to consumers of prescribed drugs.

The question of home remedies and folk remedies may be raised here. Although herbal teas and chicken soup are not in the same category as drugs or medication, such folk remedies are widely used and probably more often by poor people. Perhaps studies of American eating habits could include such investigation. One suspects that self-medication with home remedies is the first line of health defense with most people.

Nicotine

Men are more likely to be smokers than women, although the percentage gap between the sexes has narrowed considerably in the last 20 years. The Public Health Service has tracked the marked increase in female smoking during and after World War II and by the 1960s, lung cancer deaths among women began to rise. Since 1985, lung cancer has passed breast cancer as the chief cause of cancer death among women.

A survey of people 65 and older in Massachusetts showed that those *less* likely to be current smokers included respondents living alone or with their children, those who reported their health as poor or fair, and 'the frail elderly.'

The relationship between smoking and a variety of diseases is well documented. A review of studies of the metabolism of drugs in older persons concluded that the effects of aging, nicotine, and alcohol are confounded.

Illegal Substances

The occasional social use of drugs like marijuana, hashish, and even cocaine probably does occur among older individuals, and there are apparently users of illicit drugs (e.g., heroin) who began drug use earlier in life and have survived into old age. One of the widely held beliefs about opiate addicts was that they did not survive to old age, that they either died or 'matured out.' There is, however, a small number of elderly heroin-dependent people who have managed to maintain their habits and live beyond their sixties. In the mid-1970s, people over 60 years of age constituted 0.005% of the methadone maintenance population in New York City; 10 years later, the proportion had risen to 2%. These are not drug-dependent people whose habit is of recent onset; they are long-term heroin addicts who have survived. Interestingly enough, the Michigan Department of Public Health reported that for treatment admissions in 1992–93, for those 60 and over, heroin was the primarily substances of abuse for 3%.

Study of the New York City methadone-maintained survivors showed a number of variables relevant to survival: the survivors had long-lived parents, they avoided violence, and were careful about the use of clean needles. They were able to hold some drugs in reserve, used other drugs – particularly alcohol – moderately, and were generally in reasonable health when compared with same aged people in the general population.

The use of banned substances is associated with younger rather than older persons. In Michigan, treatment admissions for those under 60 show twice the percentage of younger patients whose primary substance of abuse is heroin: 6% compared to 3%. The contrast is even sharper for those whose primary substance of abuse is cocaine or crack: 18% of those under 60 and 2% of those 60 and older. Data from the criminal justice system suggest a triadic relationship: youth, criminal activity, and illegal drugs. For older persons, the criminal justice system has traditionally been involved with the homeless skid row man. In recent years, however, arrests for public intoxication have diminished, and the homeless population has become more heterogeneous.

Alcohol

Alcoholic beverages are legal and socially accepted. As such, they are used infrequently or moderately, they may be consumed in large quantities, or they may produce alcohol abuse, alcoholism, or dependents for some users. We will examine briefly the moderate social use of alcoholic beverages by older persons and then move to alcohol-related problems as manifested in abuse or dependence.

To what extent is alcohol used by older persons? It has been generally accepted that moderate drinking declines with age, but some data challenge this. Perhaps there is a historic shift so that the older cohort of the 1990s behaves differently with alcoholic beverages than the older cohort of the 1950s or 1960s. There are National Health Interview Survey (NHIS) results that suggest an increase in alcohol intake among men 65 and older, and a small increase among the same aged women. A few community-based longitudinal studies have shown an increase over time; a Framingham, Massachusetts, study showed a large increase for women. Drinking is tied to laws and social customs, and there has been a trend in recent decades toward greater acceptability. Many small communities with local prohibition laws have shifted to acceptance, and women's drinking in particular is likely to be affected by social acceptability. Older people as well as younger people are affected by changing mores.

How much of a health risk is alcohol for older persons? It is certainly true that the older population is more likely to manifest both acute and chronic illness; it is also true that this population takes more medication than younger groups. The question of age changes in hepatic blood flow and the capacity of the liver to metabolize drugs is relevant. Older people show a decrease in body water content that produces higher peak serum ethanol levels for the same amount of alcohol, which would produce lower peak levels for younger people. There are other relevant age changes, and the increased vulnerability of the brain with aging raises questions about symptomatic behavior like confusion, depression, and dementia as they may relate to alcohol intake. The general consensus, however, is that light drinking is not particularly harmful to older persons, provided they are reasonably healthy and take no medications that interact with alcohol; one drink a day is considered prudent.

Drinking Problems

Although there may be a larger number of older adults with psychoactive medication problems, they are not likely to appear in substance abuse services. It is much more likely that older adults who drink heavily or frequently and who manifest alcohol-related health and other problems will appear, voluntarily or not, at such services. In Michigan, treatment admissions of patients under 60 years of age include 62% for whom alcohol is the primary substance of abuse; for people 60 and older, alcohol is the primary substance of abuse for 86%. In a study done at a veterans' hospital 65% of the younger alcoholic men and women 80% of the older alcoholic men in the study group chose alcohol as 'substance of first choice.'

The literature on elderly alcoholism is limited, and samples are drawn from hospitals, arrest records, out-patient clinics, and housing for older people, and from community and national surveys. The issue of how patients are screened is also relevant. Although standard screening instruments are widely used, there is a question about the meaningfulness of some of the criteria for diagnosis of alcoholism. Losing time from work may be irrelevant, falls and medical problems may be more relevant. Caution is needed: surveys show a relatively low percentage of problem drinkers among those 60 and over but the size of the problem may be larger. A recent study examined the records of all hospital inpatient Medicare Part A beneficiaries, 65 and older, and reported a high prevalence of alcohol-related hospitalizations. The highest rate of such hospitalization occurs in the 45- to 64-years-old age group (94.8 per 10 000 population) and the second highest rate was in the 65-and-over age group (65.1 per 10 000 population). The alcohol-related disorders included alcohol abuse and dependence, and alcoholic liver disease, psychoses, cardiomyopathy, gastritis, and polyneuropathy.

There is a vast literature on neuropsychological or cognitive loss which is a by-product of heavy or problem drinking. Such psychological deficits have been explored in terms of functions impaired, gender differences, and the relationship of age to cognitive impairment. The latter produced a 'premature aging hypothesis,' which posited premature senescence brought on by heavy drinking; evidence about this hypothesis has been mixed. Cognitive impairment may focus on specific functions: short-term memory, non-verbal abstracting, the ability to process new information, and so forth. There is a question about the reversibility of the cognitive loss, and it is generally believed that older problem drinkers may regain loss function, given time, although the process is slow.

One of the most interesting phenomena of elderly problem drinking is the subtyping: early onset versus late onset. Some authors have defined late onset as the beginning of problem drinking around age 40; this means that a group of problem drinkers are divided into those who began problem drinking in their twenties or younger and a group that began around age 40. There is a good deal of literature that indicates that the younger-onset group will show more positive family history, more comorbid diagnoses of antisocial personality, and poorer prognosis. If we are, however, to associate onset and old age, it would be better to differentiate problem drinkers at 65 or 70 into early onset and recent onset. That a group of late- or recent-onset problem drinkers exists has been verified by a number of reports that suggest that about one-third of older problem drinkers studied qualify as recent onset. There is an interesting question whether such recent or late onset is associated with experienced stress; several investigators studying stress and drinking have come up with support for stress-as-etiology and others with stress-as-irrelevant data. Stress may be a complex phenomenon that impacts differently depending on gender, general health, socioeconomic status, life experience, and so on.

There are drinking-related factors, and it seems a reasonable hypothesis that problem drinking is more likely to occur in someone who has had a history of intermittent heavy drinking. There are changes in role and status with old age and different coping mechanisms and ability to adapt among older people. There are also shifts in the social environment, particularly for the elderly who move to a different location.

By and large, the patterns of drinking and alcohol-related problems do not seem remarkably different for older and younger problem drinkers. Older alcoholics are less likely to get into fights and less likely to have work-associated problems. They may have more alcohol-related health problems, more accidents, more concern about income, and possibly more likelihood of binge drinking.

Information about elderly female alcoholics is sparse, but a recent report compares such men and women in their 60s. The women report more marital disruption than the men and that is consistent with other age group gender comparisons; martial disruption in this age group, however, is less likely to be divorce or separation for the women, of whom 51% were widowed (compared with 18% of the men). There is a striking difference in reported age at onset: more than a third of the women report onset in the last 10 years and only 4% of the men do. Another significant gender difference is heavy or problem drinking by a significant other; as occurs in all age groups' gender comparison, more women report the spouse as a heavy or problem drinker than do men. Also, true of all age group gender comparison is that women are more likely to drink at home and less likely than men to drink in public places. Effects of alcohol as reported by the women show more negative effects (e.g., feel miserable) than do the men, the men report significantly more often that they 'get along better with people' when drinking, and there are no gender differences in aggression as a result of drinking. A final gender comparison: women are significantly more likely to report dependence and tolerance in psychoactive drug use (e.g., minor tranquilizers) than are men. Again, this gender difference appears throughout the life course.

The Role of Ethnicity

An early study, conducted in an ER of a Florida hospital, gave some figures for admissions 60 and older: 3.5% were Hispanic elderly, 6.2% were black elderly, 20.3% were white elderly.

A study of aging and ethnicity, containing material from the United States General Accounting Office, 1992, shows the following: for the 65 and older groups, a third of Whites are defined as 'poor'; for Hispanics that proportion is 69%; for Blacks, 100%. Clearly older minority group members have benefited little from affirmative action programs designed to help people through school or business. Such programs have clearly helped younger African Americans (*New York Times*, June 24, 1995).

This relates to an interesting contrast within the Black–White comparison in relation to drinking: when low-income black men are compared with low-income white men, they report significantly more drinking consequences and drinking problems. When affluent black men are compared with affluent white men, the difference in drinking problems is diminished to insignificance. Comparisons of Black–White drinking problems must therefore include not only age and gender but income as well: Significant interactions have been observed of social class, race, drinking consequences, and total alcohol-related problems.

Researchers have reported a comparison of elderly alcoholic men in treatment. There were 142 white patients, mean age 64, and 27 black patients, mean age 62. Some interesting differences were found:

1. The black patients (although drawn from the same clinical sources) showed significantly less educational achievement, occupational status, income, and current employment status. This is the age group that has benefited little from recent affirmative action programs.
2. Compared on drinking behaviors and patterns, it appeared that the black alcoholics drank larger quantities, preferred high-alcohol-content beverages, and were significantly more likely to engage in drinking in public places.
3. The black alcoholics had used or abused drugs other than alcohol to a greater extent than reported by the white alcoholics; and though both groups were elderly, the black men reported earlier age introduction to and use of 'street' drugs. One may raise the question of availability of such drugs in the community.
4. Health consequences were reported more often by the black elderly alcoholics than the white and a regression model for health consequences showed that the variables of greatest relevance were educational achievement, lifetime daily drinking average, drinking in public, and dependence on drugs other than alcohol.

An array of social, community, and institutional consequences of the heavy drinking was reviewed, and on the job and with the police, the black men reported more trouble; they also reported more rejection from friends. A regression model for social, community, and institutional consequences found the variables of greatest relevance to be educational achievement, lifetime daily drinking average, drinking in public, and race.

The triple stigma of being black, elderly, and alcoholic presents formidable challenges in finding these people, motivating them, and working at rehabilitation.

Questions have been raised about the prevalence of heavy drinking or alcohol abuse in retirement communities. There are no controlled studies (e.g., a comparison of the drinking of retirees who move to retirement communities and those who stay in their own homes). It may very well be that moving to a different state, an excess of free time, and social facilitation may play a role for some elderly drinking, but that has yet to be demonstrated.

A half century ago, there was much research interest in the chronic drunkenness offender. A disproportionately high percentage of arrests for drunkenness and public intoxication was noted among men 60 years of age and older. Two major changes have occurred in what used to be called skid row: first, a Supreme Court decision which permits arrests for antisocial behavior (e.g., disorderly conduct) but not for intoxication *per se*; second, the character and locale of the homeless population has changed. The homeless population now includes many former mental hospital patients and may be found in many different locales (airports, train terminals, etc.). In some inner cities, there has also been a drift of African Americans and Native Americans toward the old skid row neighborhoods. At present, it is more likely that the elderly homeless alcoholic will be referred to a detoxification center, but little progress has been made in measures to help the rehabilitation process.

The question of whether those older persons who live alone are more likely to be heavy drinkers is not resolved. Older women are more likely to live alone than older men, and the rate of problem drinking is considerably lower for those women than for older men. There are certainly older alcoholics who live alone, but a review of their histories may show a lifetime of alcohol abuse and an alienation of family; living alone is therefore a consequence rather than a cause of the abusive drinking. Study of this question must take into consideration the gerontological fact of differences in subgroups of the US population: the elderly person living with family members is more characteristic of some ethnic groups than others and is clearly related to socioeconomic status, family location and relationships, state of health, marital status, and so on.

Treatment and Prevention

A great deal has been written about the elderly alcohol abuser, but there are really three major questions: First, how do older alcohol abusers get into treatment? Second, what kinds of problems in diagnosis and management do such patients present and are there unique patterns in their clinical histories? Third, having made the diagnosis of alcohol abuse with or without accompanying comorbid symptoms, what are the most effective ways to proceed in treatment?

Older patients may be referred or brought to a substance abuse facility by family members, ER personnel, policemen, physicians, social agencies, or law enforcement agencies. A major basis for referral is the presence of alcohol-related health problems. One Canadian program notes that clients rarely enter a program to deal with their addiction but rather for help with other problems (e.g., accommodations, health care and the like).

The manner in which an elderly patient enters a substance abuse facility is very much a matter of his or her social networks and support systems. It may be concerned family or friends who bring in a client, but it is at least as often police or medical authorities bringing a patient who has long since destroyed family contacts.

There is, however, the question of maintaining contact. We have been studying elderly persons, diagnosable by the *Diagnostic and Statistical Manual IV* (*DSM-IV*) as alcoholics or alcohol abusers. The subjects came from hospitals, Alcoholics Anonymous, community advertising, general hospital wards, senior citizen housing, and community centers. Interviews were conducted with 104 unremitted alcoholic men currently in treatment and with 67 men, diagnosable as alcoholic but not in treatment. The groups were demographically similar and differed only in the fact that significantly more of the not-in-treatment group was retired. The most striking differences between the two groups of men occur when they are asked for self-description about their drinking (e.g., asked if they could stop drinking without a struggle after one or two drinks). Fifty-four percent of the men in treatment answered no compared with 24% of the not-in-treatment group. Examined for the nine symptomatic behaviors necessary for a diagnosis of alcohol abuse or alcoholism (*DSM-IV*), the men in treatment responded positively significantly more often than the not-in-treatment men. Drinking patterns were quite similar, but the men in treatment reported significantly more alcohol-related health problems. Finally, there was a striking difference in help-seeking behavior. In summary, older alcoholic men in treatment show greater severity of alcoholism (*DSM-IV*) and are more likely to self-describe as problem drinkers or alcoholics. They are more likely to engage in help-seeking behaviors that may include the use of the ER in a local hospital, a chapter of the Alcoholics Anonymous, seeking out a friend or relative or a physician, and so forth.

Finally, are there more effective ways of working with the elderly alcohol-dependent person? One question that has arisen is the efficacy of elder-specific

programs (e.g., group therapy with a group made up of elderly patients). Reports are mixed, but as with other special populations, if feasible, it is probably wise to offer an elder-specific group. Working with elderly patients is not remarkably different from working with other groups, but the counselor must be patient because the tempo may be slower. A nonconfrontational therapist who encourages reminiscence as well as discussion about current problems is recommended.

A note on prevention: because we are not really on firm ground in describing the antecedents or etiology of alcohol problems among the elderly, effective prevention programs must wait upon more knowledge of etiology. Although there is disagreement among researchers about the role of stress in facilitating heavy or problem drinking among the elderly, it is wise to develop aid programs for those who are recently widowed, recently retired, or even recently removed from one residence to another.

See also: Pharmacology.

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Allergic Reactivity in the Elderly

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Glossary

B Lymphocytes – Cells of the lymphocyte lineage that migrate from the bone marrow, mature in the gut-associated lymphoid tissue (GALT), and are subsequently responsible for synthesis and release of specific antibody immunoglobulins. These soluble proteins are structurally configured to react with the foreign antigen that incites their production. The immunoglobulins constitute the humoral arm of the immune response.

Immunoglobulins (Ig) – The soluble protein products secreted by activated, B cell-derived plasma cells that carry combining sites specifically reactive with the inducing antigen or allergen. Immunoglobulins are produced in five variant forms designated IgM, IgD, IgA, IgG, and IgE. Antigen or allergen-Ig union presages foreign antigen removal and destruction by a variety of mechanisms.

Interleukins (IL) – A general term for cytokines, a special class of soluble leukocyte products that serve important intercellular communication and regulatory roles and thus profoundly influence the character of the immune response.

Isotype Switch – The mechanism by which B cells 'switch' from producing immunoglobulin M (IgM) to produce IgE, IgG, or IgA molecules that continue

to carry the structural (epitope) regions reactive with the inciting allergen, but combine it with a different Fc segment. This switch changes the nature of the secondary reaction characteristics of the Ig.

T Lymphocytes – Cells of the lymphocyte lineage that migrate from the bone marrow to the thymus gland where they mature and are programmed to subsequently carry out one of a number of vital effector or regulatory roles in the operation of the immune system. These roles include functions such as controlling B cell activation or effecting specific delayed hypersensitivity responses.

Introduction

The immune system has evolved to protect against infections and to eliminate any other foreign material from the body. Ordinarily it accomplishes this without causing significant physiologic or structural damage to tissues of the individual host. When an infection is persistent, however, or when the foreign material is difficult to eliminate, the stimulus to the immune system is intensified. Also, if the individual is genetically prone to respond immunologically to even very low concentrations of foreign material such as inhaled plant pollen, an allergic or hypersensitivity state develops. These intensifications of the usual immune reactions lead to associated or concomitant forms of tissue damage in the host that are manifest clinically. It is our purpose here to look at such reactions in the elderly and how they are influenced by the aging process.

Background

In immunologic parlance, allergies or hypersensitivity states are disorders in which immune responses, sometimes directed against otherwise harmless substances, result in inflammation and consequent tissue damage. Common clinical examples of such unfortunate hypersensitivities include hay fever, allergic asthma, hives, eczema, anaphylactic reactions to insect stings, serum sickness, farmer's lung, and contact dermatitis.

Under the right circumstances, hypersensitivity reactions can develop in anyone, but there are some individuals in whom there appears to be a genetic predisposition to develop allergic responses – particularly of the immediate type. Such persons are said to be atopic. Although classic allergic reactions most often first appear in the young, they can occur at any age and although they may persist for years, they tend to wane or even disappear in the elderly. The involution of allergic reactivity in particular and immune responses in general in the aged is our focus.

Immunological reactions are ordinarily protective and are designed to prevent or to overcome infection by viruses, bacteria, fungi, or other micro-organisms. When the system is operating vigorously, it may also play a key role in suppressing the formation and growth of tumors. Thus, an intact immune system is crucial for our survival in a biologically hostile and competitive world (*see* Immune System).

It is an old clinical observation that the elderly often die of infections or of tumors that they are simply unable to overcome. In the era prior to the advent of antibiotics, pneumococcal pneumonia used to be called 'the old man's friend,' because it was so often the gentle terminal event in an otherwise long and relatively healthy life. An elderly patient with an extensive multilobar pneumonia would often develop only a modest fever of perhaps 100°F to 101°F, an elevation of the white blood count of 8000 to 10 000 with a slight 'left shift,' (i.e. the appearance of a few immature white cells in the blood). Clinically, the patient would not seem severely ill. Shortly thereafter he would die. Give the same extent of pneumonia, a young adult would develop a fever of 105°F to 106°F, a white blood count elevation of 35 000, and show many young band cells in the blood. He would feel very ill, but he would live. It was apparent that the intensity, the vigor of the systemic responses to infection in the young adult and in the elderly individual were dramatically different. Clearly, very old people did not handle infections well. The suspicion arose decades ago that this might be because the capacity to mount an immune response becomes progressively impaired as the individual ages. And indeed it does.

To understand not only why resistance to infection is impaired, but why hypersensitivity or allergic responses involute in the aged, it is necessary to describe how hypersensitivity states develop in the first place. To this end, it may be useful to review some basic features and to list the major reactive elements of the immune system.

Basic Elements and Functions of the Immune System

Immunologic responses exhibit two singular characteristics. The first of these is that the reactions are specific (i.e., a given immunologic reaction is directed only against the foreign antigen or allergen that elicited the response – although there may be some cross-reaction with allergens that are structurally related). The second is that the system is able to distinguish self from non-self. Except under rare circumstances,

such as those that obtain in autoimmune disease, the immune system simply does not react against the body's own tissues. This makes good biologic sense, because the central objective for the immune reaction is to remove from the body macromolecules and life forms that are foreign to its own makeup and are potentially harmful.

Immunological specificity resides in the receptors or recognition structures on the surface of T and B lymphocytes. The capacity to discriminate self from non-self is largely a function of the T lymphocytes. As T cells from the bone marrow pass through the thymus gland, those with receptors having a strong affinity for self-antigens and hence might react with the body's own tissues are eliminated. Others are restricted to react to foreign antigens only in conjunction with self-defining structures called the class I or class II major histocompatibility complexes (MHCs). Thymic screening and programming of T lymphocytes is a complex and incompletely understood process, but it is central to direction and control of immune responses throughout the life of the individual.

The gut-associated lymphoid tissue (GALT) is probably to B cells what the thymus is to T cells in terms of the environment it provides for B cell maturation.

Although an intact, fully functional immune system is generally very adept at discriminating self from non-self, it does not readily distinguish between foreign substances that are potentially harmful and those that are chemically or biologically innocuous. To illustrate, in allergy-prone individuals the immune system may not only react to, neutralize, and remove life-threatening bacterial toxins in the course of an infection (an eminently useful response), but may also react vigorously to inhaled, harmless animal dander protein or to plant pollen. This latter kind of immunologic reaction may result in severe allergic rhinitis or asthma – a biologic response that is misdirected, probably protective, and carries with it more harm than good.

The varied and complex functions of the immune system are subserved by a number of cellular elements and by many soluble biologically active effector macromolecules. These include enzymes and other regulatory proteins that possess stimulatory and inhibitory properties. Chief among the cellular components are T and B lymphocytes, macrophages, polymorphonuclear leukocytes, mast cells, and basophils. Among the soluble, secreted regulatory or effector molecules are the macrophage or lymphocyte-derived cytokines or interleukins (ILs) and the proteins of the serum complement cascade.

T lymphocytes and their subsets of CD4 or T helper and CD8 or T suppressor cells are extraordinarily versatile. They serve vital regulatory roles by influencing B cell functions as well as themselves effecting cell-mediated cytotoxicity and delayed hypersensitivity responses. These latter two reactions are particularly important in destroying parasites, fungi, and intracellular bacteria as well as virus-infected cells and tumor cells. B lymphocytes (and their derivative plasma cells) are responsible for antibody-mediated immune reactions.

B cells produce and release soluble antibody proteins that are tailored to the tasks of neutralizing toxins and extracellular viruses as well as facilitating phagocytosis (cellular engulfment) and destruction of bacteria. Antibodies are structurally configured to conform to and react with the surface structure of the foreign allergen or antigen. A useful analogy often used is that antibodies fit the antigen much like a key fits a lock. Antibodies are made in five immunoglobulin (Ig) isotypes, IgM, IgG, IgA, IgD, and IgE. These proteins are alike in that they react specifically with the antigen or allergen that elicited their production, but differ in their secondary properties, properties that are manifest after they combine with the inciting antigen. The structures and special reaction characteristics of the immunoglobulins are shown schematically in **Figure 1**.

Most B cells initially carry and manufacture IgM antibodies. In the face of many kinds of allergen exposure or under conditions of persistent antigenic stimulation, B cells may undergo a process called class switching. They 'switch' from making IgM antibodies to making IgG or IgA or IgE antibodies of the same antigenic or allergenic specificity. The class switch is induced and controlled by T helper (CD4) cells through their formation and release of certain of the ILs or cytokines. Class switching is achieved by retention of the Fab segment carrying the site specifically reactive with the inciting allergen, eliminating the original Fc segment and replacing it with the Fc portion of the new isotype. This results in the production of antibodies whose secondary reaction characteristics, manifest after combination with the inciting allergen, are different from those of the original IgM isotype.

As described below, B cells are ordinarily activated and induced to form antibodies by T cells that have themselves been activated by prior contact with processed foreign antigen or allergen. Thus this process of B cell activation is termed T cell dependent. On rare occasions B cells may encounter what are termed thymus or T cell-independent antigens. These include lectins, polymeric proteins, and a good number of polysaccharides with structures that are able to activate B cells directly by cross-linking B cell surface receptors with little or no T cell help.

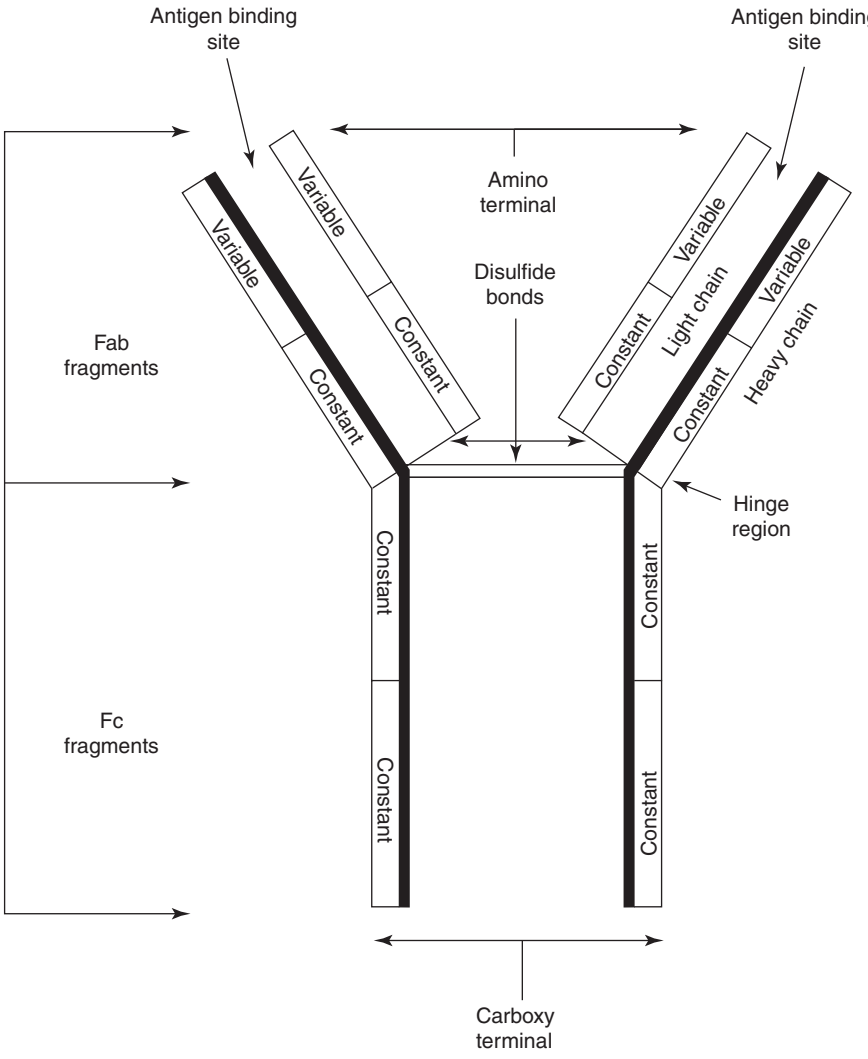

Figure 1 Basic structure of immunoglobulin antibody molecules. Variable regions of the light and the heavy chains constitute the epitope or antigen-combining site. Constant regions of the heavy chain in the Fc fragment hold structures responsible for the secondary reaction attributes of the particular antibody isotype (i.e., complement fixation and binding to cell surface receptors). Immunoglobulins differ in whether they are monomeric, dimeric, or pentameric expressions of this basic structure and in the differing chain lengths and nature of the receptors of the Fc segment of the heavy chains.

T-independent response produces mostly IgM, confirming that T helper cell lymphokines are required for class switching.

Immunologically mediated defense and hypersensitivity reactions also depend upon macrophages, phagocytic polymorphonuclear leukocytes, and metabolically active mast cells and basophils. The latter two cell types manufacture, store, and release a host of effector molecules. Acting in concert with the proteins of the serum complement cascade, the ILs, and other regulatory cytokines, these elements comprise a very intricate system that underpins immunologically triggered and directed inflammatory responses. Without these reactive capacities, humans could not resist infections or tumors and could not long survive.

Response to Allergens: Sensitization

How then do allergic or hypersensitivity states develop? The series of steps that follow and the attendant explanations identify the mechanisms that operate in the genesis and expression of the four classic hypersensitivity states as classified by Gell and Coombs. Sensitization to an airborne pollen will serve to illustrate the typical reaction sequence.

Pollen grains are breathed in through the nose and impinge on the nasal mucous membrane. The pollen is partially solubilized and a major sensitizing antigen is absorbed into the underlying tissues. Here the pollen antigen or allergen encounters and is engulfed by a macrophage. Within this remarkable cell, the allergen is dissembled into polypeptide fragments.

In association with a structure termed the class II major histocompatibility complex (MHC-II), these fragments are externalized and presented on the surface of the macrophage. By the time this allergen processing is complete, the macrophage has most likely migrated to the environment of a regional lymph node.

Next, the macrophage displaying the allergen fragment or MHC-II complex is perused by a series of helper T cells (CD4 cells). Then a particular T helper cell bearing a T cell receptor (TCR) with a structural configuration complementary to that of the pollen fragment locates and locks on to the pollen MHC-II complex through its receptor. At some point in this process, the pollen fragment is confirmed as foreign, and the T cell is activated.

This antigen-processing activity just described as a function of macrophages can also be carried out by B cells – particularly those whose surface receptors fit the foreign antigen or allergen especially well. The B cell may internalize the antigen, process it, couple it with the MHC-II complex, and present it to the appropriate T helper cell, much as does the macrophage.

The activated T helper cell undergoes clonal proliferation and differentiation. The derivative T helper cells produce and release a number of soluble substances called lymphokines, which activate those B cells that carry surface receptors akin to those on the T cell (i.e., those that are also structurally complementary and specifically reactive with the allergen). In addition, some of the activated T helper cells differentiate into effector cells that are destined to bring about delayed hypersensitivity (DH) reactions on subsequent contact with the inciting allergen (below). Some become memory T cells, cells poised for rapid mass reaction if they later again encounter the same antigen. This is termed a secondary or recall response and is more rapid than the initial or primary response.

The activated B cells in turn proliferate and differentiate into plasma cells that produce and excrete large amounts of antibody specifically reactive with the allergen. Almost invariably, several lineages of plasma cells develop, each of which manufactures and releases antibodies of differing isotypes. Thus stimulation by a single allergen, such as an airborne pollen, results in the production of IgG as well as IgE antibodies and also in the induction of a condition of delayed hypersensitivity mediated by special T helper cells.

There is one other variant of the allergic response that needs to be mentioned. Rarely, when some individuals are treated with a drug such as an antibiotic like penicillin, the drug or some metabolite of it may bind to the surface membrane of a cell (e.g., a red cell). In this attached configuration, the drug may prompt an antibody response with its own structure acting as the "foreign" determinant. The resulting antibodies will subsequently seek out and combine with any of the individual's red cells carrying the penicillin or penicillin metabolite. The combination between the antibody and penicillin determinant on the red cell may activate the complement system and the red cell may be lysed or ruptured.

Manifestations of Hypersensitivity States

Once initial contacts with an allergen have occurred and the foregoing reactions have ensued, the individual is said to have been 'sensitized.' The diversity of these responses to initial stimulation with a single allergen accounts for the different hypersensitivity reactions that result on subsequent contact with the allergen. These four kinds of reactions may be described as follows.

Type I or the immediate type of hypersensitivity, mediated by IgE antibody, is what most people recognize as classic allergies. IgE antibodies, formed after initial sensitizing contact with the pollen or other allergen, attach themselves by their Fc piece to the surface of submucosal mast cells and circulating basophils. When the pollen or other sensitizing allergen again gains access to the tissues, it reacts with the mast cell-bound IgE antibodies, cross-linking them and triggering the degranulation of the cells. This degranulation releases a series of biologically active mediators into the tissues, including histamine, leucotrienes, prostaglandins, and eosinophil chemotactic factor. These compounds cause an acute inflammatory response in the upper and/or the lower airways with vasodilation, itching, local tissue swelling, increased mucous gland secretion, smooth muscle contraction and eosinophilic infiltration. This is the mechanism behind hay fever or allergic rhinitis, allergic asthma, and the life-threatening anaphylactic reactions to bee or wasp stings or to penicillin administration in penicillin-allergic individuals.

Type II or cytotoxic hypersensitivity may be expressed in three forms. Each of the reaction sequences requires antibody. If the sensitizing foreign material is a drug or a drug metabolite that has been incorporated into a cell membrane, perhaps the membrane of a red blood cell, antibodies (most often of the IgG isotype) attach to the bound drug and attract and activate the serum complement system. This results in lysis of the red cells. If this process is sufficiently widespread, it can produce a serious hemolytic anemia. Alternatively, antibody attached to a membrane-fixed determinant may attract and

secondarily bind through its Fc receptor to what are termed natural killer cells (NK cells). These cells can, by a process not yet completely understood, also bring about lysis of the antibody-coated target cell. Finally, if the allergen-antibody-coated cell is not too large, it may be opsonized and destroyed by engulfment by a phagocytic cell, which also hooks on through a receptor on the Fc fragment of the antibody. It is worth noting that this same type of hypersensitivity reaction in its three variant forms is thought to operate in destroying tissue in a number of autoimmune states. In autoimmune diseases, the membrane-bound target is not a foreign drug or allergen, but is presumably a normal cell constituent mistakenly viewed as foreign by the immune system.

Type III or immune complex hypersensitivity is the immune reaction responsible for a number of clinical conditions, including hypersensitivity lung diseases, serum sickness, and immune complex kidney disease. Antigen exposure in this disorder is usually intense and protracted. This leads to a quantitatively impressive antibody response because the sensitizing antigen or allergen is often cleared from the body with difficulty. The allergen and the antibodies combine and then fix complement, which results in an inflammatory reaction. Vascular walls are damaged in the process and their permeability is increased. As a result of this initial damage, the deposition of the immune complexes in the vascular walls and tissues may then worsen and perpetuate the inflammatory cycle by attracting polymorphonuclear leukocytes that further accentuate local tissue damage. When such complexes deposit in renal glomeruli, kidney disease results. The presence of immune complexes in the circulation is not an uncommon event. Ordinarily they are rapidly removed by circulating red cells (picked up by red blood cell complement receptor) or by phagocytosis. It is when the complexes are formed in the presence of antigen excess that they deposit in tissues and tissue damage ensues.

The mechanism of Type IV hypersensitivity (also termed tuberculin, contact, or delayed hypersensitivity) is antibody independent and is mediated by T cells alone. The very descriptive term *delayed* hypersensitivity is employed because the reaction becomes manifest and reaches its peak only after about 48 hours following reexposure to the sensitizing antigen. A subset of T cells of the CD4 type especially programmed to secrete cytokines IL2 and interferon (IFN) gamma appear to be responsible for precipitating the Type IV inflammatory reaction and the consequent tissue damage. If it is sufficiently intense, a local delayed hypersensitivity reaction can result in vascular occlusion and tissue necrosis. Delayed hypersensitivity underlies the disease contact dermatitis, as in the reaction to poison ivy, and under such circumstances is clearly deleterious. Paradoxically, as noted earlier, this same hypersensitivity state is an absolutely crucial feature of the complex immune response, which serves to contain virus infections and to control mycotic and intracellular microbial infections such as tuberculosis. This is also the reaction responsible for the diagnostically useful tuberculin skin test.

Involution of Hypersensitivity States with Aging

Again, the vigor of immune responses, including allergic or hypersensitivity reactions, diminishes in the elderly. The nature of the impairment has been studied extensively over the past two decades, and we now know some of the bases for immunologic senescence. These changes are best understood in light of the mechanisms producing the hypersensitivity reactions just described.

Although there are some variations in published reports, the overall number of immunocompetent cells and their various subsets does not appear to change much with advancing age except very near the end of the individual's life. This phenomenon has been well documented in the Baltimore Longitudinal Study of Aging. In the majority of the subjects, the absolute peripheral blood lymphocyte count remained within the normal range into advanced age. However, a marked lymphopenia was found in men in the 3 years preceding their deaths. Although in most studies in humans, B cell and macrophage numbers appear to be maintained, and the total number of T cells may remain nearly constant, there seems to be an increase in the proportion of immature T cells in the elderly.

This release of immature T cells into the peripheral blood of the elderly may reflect changes in the thymus, the organ that consistently shows the most dramatic changes as humans grow older. This key structure, so important in the development and management of T cell activity, begins to involute at puberty and continues to do so until middle age. After the age of 50, the thymus contains less than 10% of its previous immunologically active cell mass – most of which is replaced by adipose tissue. As this process progresses, there is a concomitant decline in the synthesis and release of regulatory thymic hormones. These hormones are no longer even detectable after the age of 60 years. Some level of thymic activity, however imperfect, is probably maintained in the elderly because T precursor cells continue to leave the bone marrow and home in on the thymus. It appears that the positive and negative

selection, the maturation, and programming of the T cells in the thymic environment is impaired. This also may be a key factor that contributes to the increasing autoimmune activity seen in the aged.

Given the extensive involutional changes in the thymus, it is perhaps not surprising that the T cells more than B cells are the most directly and profoundly affected in the aging process. The extant, long-lived peripheral T cell population in the blood, the lymph nodes, and the spleen may also develop functional deficits over time. These are manifest in important ways. Cell-mediated immunity and delayed hypersensitivity, both manifestations of direct T cell effector activity, may be seriously compromised. It has been demonstrated that a group of individuals over 80 who became non-reactive or hyporesponsive in tests for delayed hypersensitivity showed a higher mortality over a 2-year period than did a comparable group who were not hyporesponsive. The loss of delayed hypersensitivity and impairment of specifically directed cytotoxic cell-mediated immunity opens the door for reactivation of latent viral, mycotic, or tubercular infections.

Furthermore, perhaps reflecting the repeated immunologic stimulation that accrues over the years, the elderly show increasing numbers of T cells committed to memory function.

T cells from the aged when placed in culture show a marked decrease in their ability to proliferate when exposed to phytohemagglutin (PHA) or concanavalin A, two potent mitogens (compounds that stimulate cell division). Among old T cells, only about half are able to respond to such stimulation. Furthermore, when they do respond old T cells show an impairment in calcium uptake, a decrease in enzyme induction, a decrease in protein synthesis, and a decrease in nuclear response to intracellular signals.

All these deficits in the efficiency of intracellular processes diminish the replicative capacity of the T cells. They also substantially decrease the T cell's ability to form and release those soluble regulatory substances so crucial to the T cell role in arousing and controlling the overall immune response.

In this regard, the decline in IL2 production has been extensively studied and the mechanism of the failure defined in some detail. Deficiency in IL2 production has broad ramifications. It affects not only T cells, but B cells and antibody production as well. Deficits in T cell synthesis and release of other ILs, of B cell differentiation factor, and of B cell growth factor decreases the effectiveness of intercellular communication and thus of immunoregulation.

Witness to this failure in immunoregulation in the aged is the decrease in B cell capacity to mount a vigorous specific antibody response to T cell-dependent allergenic or antigenic stimulation. It appears that the B cell response to T cell-independent antigens may be less compromised. The levels of such natural antibodies as isoagglutinins against blood group antigens also decline in the aged. Oddly, other elements of the B cell population show increases in the production of autoantibodies. Fortunately, although old people show an increase in autoantibody activity, they do not often show a concomitant increase in autoimmune diseases.

Defects in regulatory function are also manifest in the proliferation of single B cell lineages in the elderly, which synthesize and release large amounts of monoclonal 'antibody' of obscure specificity. These latter immunoglobulins are produced in such quantity that they are manifest as 'M' peaks on serum electrophoresis. They appear to be produced by a B cell clone that has escaped normal T cell suppressor or other dampening regulatory influences. Among 90-year-olds, as many as 15 to 20% may show M peaks. Such monoclonal 'gammopathies' not infrequently presage the onset of fatal lymphoproliferative malignancies in the elderly.

Macrophages seem to withstand the aging process relatively well, but are not entirely spared. Their number seems not to diminish much with time, and they appear to retain phagocytic and antigen processing and presentation processes fairly well. Importantly, however, their capacity to produce ILs and other soluble factors may be impaired as the individual ages.

It appears to be relatively well established that classic allergic or immediate (Type I) hypersensitivity reactions are far less frequent in old age. The reasons appear to be several. Serum IgE concentrations are significantly lower in the elderly than in the young, and the differences are most marked in males. The specific IgE response to administration of diphtheria toxoid has been found to be lower in the aged, and the intensity of the immediate skin test 'weal and flare' reaction is reduced in old people. It is suggested that these findings are not only because of a decrease in the ability to make IgE, but are also a reflection of impaired mast cell function.

Some particularly elegant work has shown a decrease in the production and the response to IL4, the cytokine that is key to controlling the synthesis and release of IgE. As previously noted, this Ig isotype is responsible for immediate hypersensitivity reactions or classic allergies. The impressive decline in IgE explains the disappearance or the diminished intensity of allergic rhinitis and allergic asthma in patients who are up in years. Severe IgE-mediated reactions such as anaphylaxis can occur in the elderly, but they

are rare. The involution of the atopic state ranks among the few comforts of growing older.

Serious impairment of immune responses including those in the realm of allergic or hypersensitivity states carries ominous portent. Thus, assessment of the condition of the immune system in the elderly can provide important prognostic insights.

See also: Immune System.

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Andropause

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Glossary

Anabolic – Tending to build up new tissue components and favoring growth and repair.

Dihydrotestosterone – A potent androgen made from metabolism of testosterone by desaturation (deletion of two hydrogens) of the A ring.

Estradiol – Main female sex steroid hormone that mediates breast and feminine body habitus development, supports female reproductive function, and helps sustain bone mass.

Gonadotropin – Protein hormone produced by the pituitary gland that regulates testis and ovarian function.

Receptor – Protein to which a hormone binds specifically and that mediates effects of hormone at cellular level.

Steroid – Fat-soluble molecule derived from cholesterol having four rings, three of six carbons and one of five carbons.

Testosterone – Main male sex steroid hormone that mediates masculinization of fetus and male puberty, and sustains male sexual function and body habitus.

Introduction

The major male sex steroid hormone, testosterone (T), is synthesized from cholesterol and secreted mainly by the Leydig (interstitial) cells of the testes in response to pituitary luteinizing hormone (LH). LH, a large glycoprotein hormone, is, in turn, produced in response to neurally timed episodic pulses of gonadotropin-releasing hormone (GnRH), a decapeptide secreted by neurons in the hypothalamus, which reaches the pituitary via a portal venous network. GnRH and LH secretion are controlled by a feedback system in which T and its aromatization product estradiol inhibit hypothalamic and pituitary secretory activity. T circulates about 40% bound to sex hormone-binding globulin (SHBG). Of the fraction of T not bound to SHBG, called the bioavailable T, most is loosely bound to serum albumin, leaving only 1–2% dissolved in plasma as free T. T acts mainly via the androgen receptor (AR), which participates in a nuclear receptor complex and stimulates or inhibits activity of specific genes by binding to upstream androgen regulatory sequences. In many androgen target cells, T is converted to dihydrotestosterone (DHT) by the enzyme 5α-reductase. DHT is a more potent androgen than T, having a higher binding affinity for the AR. DHT also circulates partially bound to SHBG, usually at about 10% of the concentration of T. In addition to stimulating maturation of male genitalia, body habitus, and hair patterns at puberty and maintaining male libido, T has important lifelong effects on body composition, especially skeletal muscle mass and fat distribution, bone metabolism, cognition, and affect.

Extensive clinical research has been conducted investigating whether a decline in male hormones with age (andropause) occurs in men. Yet the questions of the extent to which T decreases as a concomitant of the normal aging process and, more important, whether such decreases represent functional male hypogonadism remain open. Critical issues bearing on the advisability (or inadvisability) of T replacement in elderly men have not been resolved and require further investigation. The key questions to be answered in order for physicians to make appropriate clinical decisions are the following:

- Does T decrease with age in men and, if so, are levels consistent with hypogonadism in significant numbers of older men?
- To what extent are changes in T levels clinically significant?
- Are typical aging changes in physiology, body composition, and function consistent with hypogonadism?
- Do typical age-related changes correlate with endogenous androgen levels?
- Are there potential benefits from treating older men with T alone or in combination with other hormones?
- What serious adverse effects occur with androgen replacement in elderly men?

These questions have not been answered satisfactorily. However, some research results suggest that T replacement may be useful in a significant number of older men.

Is There a Decrease in T Levels with Age?

A few initial cross-sectional studies of T levels in men of various ages failed to detect significant decreases in older men. However, in the majority of cross-sectional investigations declines in circulating androgens with age have been observed (e.g., **Figure 1A**). In addition, SHBG levels appear to increase with age. Thus, for the same concentration of total serum T, the level of free or bioavailable T tends to be lower in old men than in young men, and the age-related decrease in free or bioavailable T is more pronounced than that for total T (**Figure 1B**). In addition, longitudinal studies have confirmed progressive linear reductions at fairly constant rates of about 1% per year for total T and 1–2% per year for non-SHBG-bound T with aging in healthy men, beginning by age 30. This change has been well defined in the Baltimore Longitudinal Study on Aging (BLSA) population and is shown in **Figures 2A** and **2B**. Estimates of the frequency with which T concentrations reach hypogonadal levels (i.e., two standard deviations below the mean for young men) in men of different ages vary from 30–40% in men over 65 to as high as 70% in men in their 80s. These estimates suggest that millions of elderly men have hypogonadal serum T levels as conventionally defined. This condition has been referred to as partial androgen deficiency of aging men (PADAM). The extent to which such men might benefit from hormone replacement is an extremely important, but as yet unanswered, question.

Is the Lower T in Aging Men Clinically Significant?

In apparently healthy men, there are significant age-related decreases in lean body mass and bone density. These changes in body composition are accompanied by diminished strength and VO_{2max} (fitness) and are caused in part by muscle loss (sarcopenia). Negative calcium balance and loss of bone mineral leading to

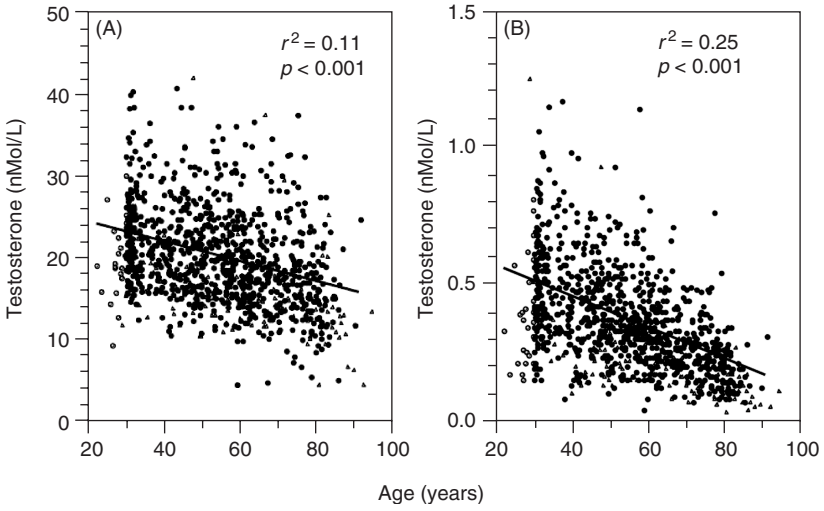

Figure 1 Effects of age on serum T (A), free T index (B) in men in the Baltimore Study on Aging (BLSA). Individual data points from the earliest available (usually first) visits during 1963–94 are shown as filled circles and the additional set of 120 serum samples from later visits (1995–98) are plotted as filled triangles. Total T concentrations and free T index values decreased linearly with increasing age. Reproduced from Harman SM, Metter EJ, Tobin JD, *et al.* (2001) Longitudinal effects of aging on serum total and free testosterone levels in healthy men. Baltimore Longitudinal Study of Aging. *Journal of Clinical Endocrinology and Metabolism* 86(2): 724–731.

osteoporosis is a problem for men as well as women. Although osteoporotic fractures are about one-third as frequent at any age in men as in women, hip fractures are more likely to be fatal in men. In addition, total and central abdominal fat increases with age. Changes in fat volume and distribution impair insulin sensitivity so that aging leads to higher fasting and postprandial blood sugar and increases the risk of type 2 diabetes. Deleterious alterations in LDL and HDL cholesterol and triglycerides also occur, producing greater risk of cardiovascular disease. Finally, normal aging is associated with reductions in total body protein synthesis, subtle impairments in cognition with deficits in memory and concentration, loss of libido, diminished sexual activity, and greater prevalence of erectile dysfunction.

Male hypogonadism resembles normal aging in certain particulars. In non-elderly hypogonadal (T < 250–300 ng/dl, depending on the laboratory) men, there are also reductions in lean body mass and muscle strength, increases in total and abdominal fat and impaired glucose tolerance, lower levels of sex drive and activity, and, in some studies, affective and cognitive dysfunction, including depression.

The associations suggest that the aging phenotype may be, in part, related to decreases in sex steroid hormones. If this hypothesis is correct, then the extent of the decreases in bioavailable T levels in elderly men should parallel and predict losses of lean body mass, bone density, muscle strength, cognitive function, and sexual capacity, as well as the increases in body fat and insulin resistance. Some studies in older men have demonstrated significant relationships between total or free T levels and lean body mass or muscle strength. Positive correlations have also been observed between bone mineral density and T levels, but these are weaker than those for estradiol. T concentrations have also been reported to be negatively correlated with body mass index (BMI) and percent body fat as well as with increased intra-abdominal fat and insulin resistance. Consistent with the preceding, there appears to be an overall greater risk of the metabolic syndrome (a combination of central obesity, hypertension, and insulin resistance) in older men with low T levels. Sexual activity and libido have been reported to be better in old men with higher T levels. Some studies have suggested a correlation between T and erectile function, but these data are weak. Finally, higher T levels have been correlated with improved performance on particular cognitive axes in some studies but not in others. Recently, it has been suggested that elderly men with low T levels may be at greater risk for Alzheimer's disease.

Are There Benefits of T Treatment in Older Men?

In studies of non-elderly hypogonadal men, T replacement has increased lean mass, muscle size, and strength while diminishing central obesity and insulin resistance. T may increase perfusion of brain regions involved in cognition and improve cognitive function in hypogonadal men. Results of investigations to determine whether T in physiological doses would have similar beneficial effects in elderly men

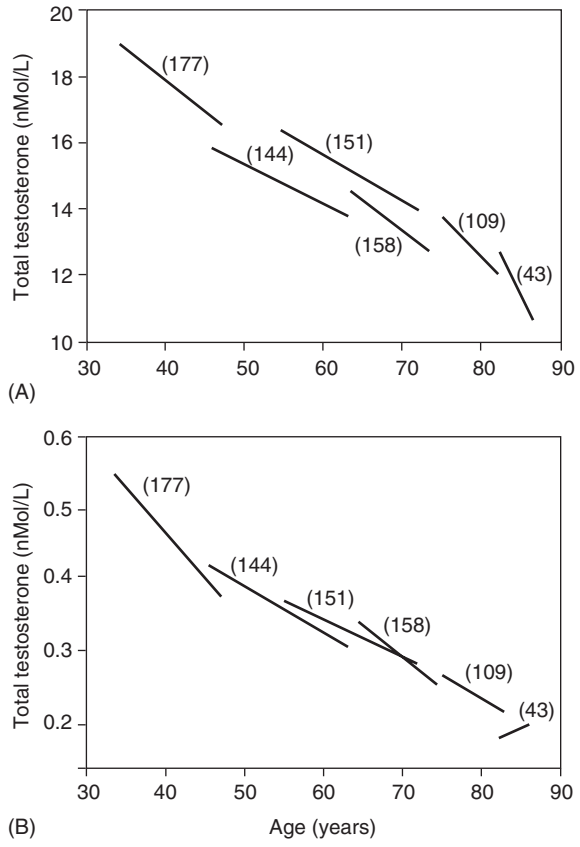

Figure 2 Longitudinal effects of aging on date-adjusted T (A) and free T index (B). Linear segment plots for total T and free T index vs. age are shown for men with T and SHBG values on at least two visits. Each linear segment has a slope equal to the mean of the individual longitudinal slopes in each decade, and is centered on the median age, for each cohort of men from the second to the ninth decade. Numbers in parentheses represent the number of men in each cohort. With the exception of free T index in the ninth decade, segments show significant downward progression at every age, with no significant change in slopes for T or free T index over the entire age range. Reproduced from Harman SM, Metter EJ, Tobin JD, *et al.* (2001) Longitudinal effects of aging on serum total and free testosterone levels in healthy men. Baltimore Longitudinal Study of Aging. *Journal of Clinical Endocrinology and Metabolism* 86(2): 724–731.

with PADAM have been inconsistent, perhaps due in part to the employment of varying androgen doses and routes of administration, varying durations of treatment, and differences in populations studied.

In 60- to 75-year-old men, graded doses of T during suppression of pituitary LH secretion with a GnRH analogue produced dose-related responses of lean mass, muscle strength, and fat mass resembling those observed in young men, suggesting that elderly men may respond to androgens similarly to the way younger men do. **Table 1** presents results of several studies of T treatment in older men. As shown, gains in lean body mass have tended to exceed those in muscle strength or VO_{2max}. Although treatment with T has been reported to decrease body fat in men over 65 and abdominal fat mass in middle-aged men with low to low-normal T levels, in one study 6 months of relatively low-dose T injections given to old men did not cause significant decreases in, or redistribution of, body fat.

Loss of bone mineral density (BMD) was not significantly improved in men over age 60 given T by scrotal patch with baseline low to low-normal T levels. However, loss of BMD was significantly ameliorated in this same study in men whose T levels at baseline were <200 ng/dl. Other studies of T effects on bone in older men have found that T treatment for 36 months prevented loss of BMD at the lumbar spine ($P<0.001$) and at the hip ($P\leqslant 0.02$), and that diminished bone loss occurred in the femur, but not in the lumbar spine.

Positive effects of T treatment on libido and of dihydrotestosterone treatment on erectile function have been reported in older men. In a study of cognition, scores on the Digit Symbol and Trailmaking B tests were slightly but not significantly better in T-treated than in placebo-treated men. Androgen treatment may improve cognitive and visual-spatial skills in elderly men with mild to moderate Alzheimer's disease. Finally, some evidence suggests that T may moderate depression in older men with low T levels.

The question of T interaction with other hormones was addressed in a study in which T was given to healthy men over 65 with low T and insulin-like growth factor-1 (IGF-1) levels for 6 months, alone or with human recombinant growth hormone (rhGH). The T plus GH combination produced greater increases in lean body mass and muscle strength and decreases in body fat than were seen with T alone. It may be the case that administration of T in older men with low GH levels, another endocrine concomitant of aging, may result in suboptimal responses.

What Are the Risks of T Treatment?

Potential benefits of T treatment in older men must be weighed against risks of adverse effects. In young hypogonadal men, physiological T replacement is low risk. In older men, risk–benefit ratios may be less advantageous. Minor adverse effects of T treatment include fluid retention, erythrocytosis, and sleep apnea, problems that may be more common in old men. Of greater concern are possible increases in atherosclerosis and greater risk of prostate cancer.

T treatment may lower HDL cholesterol and raise LDL cholesterol. Evidence indicates that excessive doses of anabolic steroids taken to build muscle mass may lead to premature coronary vascular disease (CVD). However, low T levels may also be associated

Table 1 Changes in lean and fat body mass, bone mineral density, muscle strength, and oxygen capacity (VO_{2max}) in old men treated with testosterone in five studies

Source	*Study design*	*Measure*	*Change in placebo group*	*Change in T group*	P *value*
		Lean body mass (kg)	0.2±1.5	1.9±2.0	<0.001
		Body fat mass (kg)	−0.7±3.1	−3.0±3.7	<0.001
Snyder *et al.,* 1999 (65)	96 men >60 years old using placebo or T patch for 36 months	Knee ext. strength 60° (ft lb)	−12.8±17.6	−12.0±13.5	NS
		Knee flex strength 60° (ft lb)	−4.9±12.3	−5.9±11.0	NS
		15 Stairs – time (s)	0.1±2.0	0.6±2.0	NS
Snyder *et al.*, 1999 (71)		BMD L2–4 (%)	2.5±0.6	4.2±0.8	NS
		BMD femoral neck (g/cm^2)	−0.7±0.7	0.8±0.6	NS
Amory *et al.*, 2004 (72)	70 men >65 years old given T enanthate with or without finasteride or placebo for 36 months	BMD lumbar spine (%)	1.3±1.4	10.2±1.4	<0.001
		BMD femoral neck	−0.2±0.7	2.7±0.7	⩽0.02
Blackman *et al.,* 2002 (66)	36 men >65 years old given T enanthate 100 mg or placebo every 2 weeks for 6 months	Lean body mass (kg)	0.0±1.5	1.6±1.1	<0.0001
		Body fat mass (kg)	0.1±1.2	−0.9±1.7	<0.05
		Upper body strength	6.9±5.3	8.7±5.0	NS
		Lower body strength	3.2±1.9	1.1±2.3	NS
		VO_{2max} (ml/kg)	−1.3±1.4	−0.2±0.8	NS
Kenny *et al.*, 2001 (73)	67 men >65 years old given two 2.5 mg T patches or placebo for 12 months	BMD femoral neck (g/cm^2)	−0.015±0.01	−0.003±0.01	0.015
		BMD lumbar spine (g/cm^2)	0.015±0.16	0.008±0.19	NS
		Percent body fat (kg)	−1.7±0.6	−0.3±0.5	0.08
		Lean mass (kg)	1.0±0.5	0.2±0.6	0.11
		Strength (Newtons)	240±	171±	NS
Singh *et al.*, 2004 (70)	24 men age 60–75 treated with 25 mg or 300 mg doses of T enanthate while suppressed with GnRH agonist	Fat free mass (kg)	25 mg group	300 mg group	
		Body fat mass (kg)	−0.3±0.5	5.6±0.5	0.05
		Leg press strength (kg)	0.1±0.5	−2.2±0.5	0.05
			0.8±6.7	51.7±4.7	0.05

Reproduced from Harman SM (2005) Testosterone in older men after the Institute of Medicine Report: where do we go from here? *Climacteric* 8(2): 124–135.

with greater CVD risk. For example, in a study by Muller *et al.*, free T levels in elderly men were directly related to rate of progression of common carotid artery intimal medial thickness, independent of cardiovascular risk factors. As noted previously, low T levels have also been associated with increased abdominal fat and insulin resistance and the metabolic syndrome. Finally, transdermal or injected T in men with low T levels may improve lipid pattern, reduce abdominal fat, decrease insulin resistance, lower triglycerides, and lead to more beneficial cardiac risk profile overall. Nonetheless, the net influence of exogenous T on atherosclerosis progression or incidence of CVD remains unknown.

The most worrisome issues with regard to T in older men are potential adverse effects on prostate cancer risk and benign prostatic hyperplasia (BPH). In a study in which elderly men were treated with T for 3 years, one treated group took T alone and the other T plus finasteride (F), a 5α-reductase inhibitor, given to block DHT production. PSA increased significantly in the T group, and prostate volume changes were smaller in the T plus F group. Effects of T on bone and muscle were similar in men treated with T or T plus F.

Novel pharmaceuticals called selective androgen receptor modulators (SARMs), which function as partial androgenic agonist/antagonists in prostate and seminal vesicle but full anabolic agonists in muscle and bone, may improve male anabolism but avoid potential effects on prostate disease. With regard to this putative risk, it is of note that most observational studies have failed to detect a significant association of endogenous T levels and prostate cancer incidence. Enlargement of the prostate and small increases in serum PSA have been observed in older men given exogenous T, without notable worsening of urinary tract symptoms or increased frequency of prostate

cancer. However, in the absence of a large randomized trial of prostate effects of T, this question will remain a serious consideration.

Summary and Conclusions

T, and to a greater extent bioavailable and free T, decrease with age in otherwise healthy men, reaching hypogonadal levels in a substantial fraction (PADAM). T replacement at physiological doses in men with PADAM may have potential for reducing loss of muscle and improving strength as well as diminishing body fat and benefiting glucose tolerance. T may even help protect against cardiovascular disease and preserve cognitive function. However, the population most likely to benefit from such treatment is undefined. Moreover, there is insufficient reliable information as to potential adverse effects of T replacement in older men. Despite the absence of definitive information on risk–benefit ratios, large numbers of middle-aged and older men are using exogenous T to treat or prevent effects of normal aging. The number of prescriptions for T has increased in the last decade from hundreds of thousands into the millions annually, in part fueled by the availability of non-injectible products such as skin patches, dermal gels, and buccal and sublingual systems. Only new trials of sufficient size and duration to determine with confidence the magnitude of benefits and incidences of adverse outcomes can provide the data needed for physicians to confidently advise men with regard to the use of male hormone replacement.

See also: Dementia: Alzheimer's; Menopause; Prostate.

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Anxiety Disorders

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Glossary

Agoraphobia – Disorder characterized by an irrational fear of leaving the familiar setting of home or venturing out into the open.

Anxiety – Excessive or irrational fear associated with a real or anticipated stimulus.

Generalized Anxiety Disorder (GAD) – Disorder characterized by worry that is excessive and difficult to control and that lasts for 6 months or more.

Panic Disorder – Disorder characterized by recurrent, unexpected panic attacks and consequent fear of having another attack.

Introduction

Anxiety is characterized by excessive or irrational fear associated with a real or anticipated stimulus. Anxiety is often accompanied by phobic avoidance and a constellation of somatic symptoms. Phobic avoidance may be seen as an adaptive mechanism that enables the individual to minimize exposure to situations that may be anxiety provoking. But such avoidance can become maladaptive when it leads to significant behavioral changes, including social isolation and agoraphobia. Common somatic manifestations of anxiety include cardiovascular (palpitations, non-cardiac chest pain), respiratory (dyspnea), neurological (dizziness, headache, tremulousness), laryngeal (lump in the throat), and gastrointestinal (diarrhea, abdominal cramps) symptoms. The somatic complaints are often the impetus for the individual to seek treatment, usually with a primary care provider, and can result in extensive medical workups that fail to find an underlying medical etiology for the symptom.

Clinically significant symptoms of anxiety are common in the elderly. Such symptoms may represent the physiological consequences of a treatable medical illness, the result of psychiatric illness, and/or an exaggerated or normal response to life events. Anxiety disorders are often chronic conditions, persisting in various forms across the life span, and in the elderly they exist in a number of clinical presentations. For example, anxiety may be chronic and relapsing, as with a manifestation of a lifelong disturbance or condition. Alternatively, anxiety may present in the short term, in response to an acute stressor. Anxiety is also frequently associated with other chronic problems in the elderly, such as cognitive decline and impairment, medical problems in self and/or spouse, and depression.

This article briefly reviews the epidemiology, etiology, and differential diagnosis of anxiety in the elderly and discusses treatment and management issues in this population.

Epidemiology of Anxiety in Later Life

At least one in five people over age 65 suffers from a mental disorder, and it is anticipated that by 2030, the number of elderly with psychiatric disorders will equal or exceed the number of those in younger age groups with these disorders. Of psychiatric illnesses in older adults, anxiety disorders are among the most common, with clinically significant symptoms affecting approximately 10–20% of individuals over 55 years of age. Much of what we know about the epidemiology of anxiety disorders in older populations is extrapolated from findings in younger adult populations. However, the prevalence of these disorders does not appear to be consistent across the life span, as noted later. A listing of the various anxiety disorders as recognized in the 4th edition of the *Diagnostic and Statistical Manual for Mental Disorders* (DSM-IV) is presented in **Table 1**. It is important to note that the majority of older adults with anxiety, however, will fail to meet criteria for a specific disorder, due in part to insufficient symptom intensity and frequency, but also due to limitations in current diagnostic classification systems in capturing the quality of anxiety in the elderly, often characterized by anxious mood, tension, and diffuse somatic complaints. Nevertheless, the anxiety can be moderately disabling and deserving of clinical attention.

As with depression, anxiety can cause significant impairment in functioning and quality of life in the elderly. It has been shown that older adults (over 75) taking medication for anxiety, depression, or insomnia report significantly worse physical functioning and mental health and greater pain and role limitations due to physical impairment when compared to peers who were not taking psychotropic medications.

Generalized Anxiety Disorder (GAD)

Generalized anxiety disorder (GAD) is considered by many clinicians to be the most common anxiety disorder in the elderly, in whom it is more prevalent

Table 1 Anxiety disorders and their core symptom profiles

Disorder	*Core anxiety symptoms*
Generalized anxiety disorder (GAD)	Worry, anxiety, tension
Panic disorder	Recurrent, unexpected panic attacks; may be accompanied by agoraphobia
Agoraphobia without panic disorder	Avoidance of situations due to fear of inability to escape
Obsessive-compulsive disorder (OCD)	Obsessive thoughts; compulsive behaviors; marked anxiety may develop if behaviors are interrupted
Post-traumatic stress disorder (PTSD)	Following a traumatic event that is associated with intense fear, horror, or helplessness; intrusive recollections and re-experiencing symptoms; avoidance and numbing; hyperarousal
Social phobia[a]	Fear and avoidance of a variety of social encounters; often accompanied by autonomic arousal
Specific phobia	Fear and avoidance of specific objects/situations

[a] Also known as social anxiety disorder.

than in younger adult populations. GAD is characterized by worry that is excessive and difficult to control and that lasts for 6 months or more. The worry does not focus on any specific topic and is accompanied by a variety of somatic complaints, such as fatigue and muscle tension. GAD is frequently comorbid with major depression, a presentation that portends a more chronic course, takes longer to respond to antidepressant medication, and is less likely to remit.

Agoraphobia

Another disorder that is more common in the elderly than in younger adults is agoraphobia, a condition characterized by an irrational fear of leaving the familiar setting of home or venturing out into the open. While commonly associated with panic attacks in younger age groups, this is not necessarily the case in the elderly, in whom agoraphobia often develops following a traumatic event. Agoraphobia can be most disabling to older adults, especially if they live alone. Elders literally feel trapped in their homes and therefore do not attend to necessary daily activities, including appointments with health-care professionals.

Panic Disorder

Panic disorder is a condition characterized by recurrent, unexpected panic attacks and consequent fear of having another attack, a fear that ultimately leads to significant distress and behavioral changes. Panic disorder is a condition that typically presents in the late teens to mid-30s, but rarely begins in old age. While qualitatively similar to panic attacks in younger adults, panic attacks in the elderly tend to be less frequent, with less intense symptoms, and are associated with fewer avoidance behaviors. Panic attacks that begin in late life should prompt careful assessment for depression, an underlying medical illness, or medications that may be contributing to the symptoms.

Obsessive-Compulsive Disorder (OCD)

Obsessive-compulsive disorder (OCD) with late life onset is uncommon. The development of obsessive thoughts and/or compulsive behaviors in this population should prompt assessment for other psychiatric disorders such as delirium or psychotic depression. In addition, the clinician should review with the patient and family a lifelong pattern of such behaviors that perhaps increased in frequency and/or severity at the time of evaluation.

Social Phobia

Social phobia, or social anxiety disorder, is the most common anxiety disorder, typically with onset in adolescence. While little is known about the epidemiology of this condition in the elderly, community studies have shown a slight increase in the prevalence of social anxiety disorder in the 50–60 age group. This group may represent individuals who had lifelong underlying social anxiety that was previously manageable and that did not manifest as a disorder until later in life, at a time when exposed to social situations that were no longer avoidable, e.g., having to enter the work force for the first time following divorce or the loss of a spouse.

Post-traumatic Stress Disorder (PTSD)

The epidemiology of post-traumatic stress disorder (PTSD) in the elderly is not well characterized. Much of what we know about PTSD in this population is derived from retrospective studies of survivors 40–50 years after mass trauma, primarily interpersonal trauma (e.g., Holocaust survivors, World War II combat veterans). Relatively low rates of PTSD have been observed in these populations, and possible explanations for this finding are as follows: individuals with more severe PTSD symptoms (particularly avoidance) may not have participated in the studies;

PTSD may be associated with greater morbidity and mortality over decades and many with the disorder may have died in the intervening years; and the salutogenic effects of trauma contribute to lower prevalence rates, with psychological development favoring personal growth and wisdom. However, it is important to recognize that some symptoms, such as insomnia and nightmares, may persist for decades and that stressors of aging do not necessarily exacerbate PTSD. Further, post-traumatic psychological sequelae may complicate or worsen physical illness and health-related functioning. To this end, it has been suggested that PTSD symptoms may tax the body's protective and self-regulatory systems, thereby exacerbating illness while also reducing the individual's capacity to recover and function fully in life.

Anxiety Secondary to Changes in Physical Health

Anxiety can also present in the setting of failing physical health later in life. For example, fecal or urinary incontinence can be associated with shame and embarrassment, which may present as anxiety and social isolation. In an individual who develops a terminal illness, his or her concerns need to be considered in the context of possible retirement, loss of (or leaving) spouse, other medical disabilities, and other losses. Auditory sensory loss may lead to communication breakdown, which can be compounded by personal, situational, and environmental triggers. Older adults who are unstable on their feet may be especially anxious when required to walk in a crowded area, such as a mall or a busy medical clinic.

Etiologic Factors in Anxiety in the Elderly

The etiology of anxiety disorders is considered to be multifactorial, with significant contributions from both genetic and environmental influences. In the elderly, however, heritable factors have a lower impact, and greater emphasis is placed on the role of the biochemical alterations that occur with aging and illness and with neurodegenerative changes. The role of medications should also be considered, as medication side effects or as drug interactions in the setting of polypharmacy. For example, an older adult may be treated with a synthetic thyroid preparation and experience heightened anxiety secondary to a pharmacologically induced hyperthyroidism.

Psychological and social factors also play a prominent role in development of anxiety in this population. For example, aging adults may become anxious in stressful situations that they may have handled without difficulty when younger, such as driving in heavy traffic, or in social situations when subjected to criticism or embarrassment. Older adults may develop anxiety when in unfamiliar situations (an experience that may be made worse by mild memory impairment), such as when awakening in a strange environment when traveling. They may have realistic safety concerns that become exaggerated, causing subsequent changes in behavior, including limitations in social interactions. It is also important to consider issues associated with life transitions, such as loss (of family, spouse, peers/supports, health), financial stressors, and moving or downsizing.

From a psychoanalytic perspective, helplessness secondary to the following events may serve as a precipitant for anxiety: loss of partner or other supports, medical infirmity, sensory loss, and loss of mastery or control.

Issues in Proper Diagnosis

Despite the high prevalence of anxiety in the elderly, these disorders have not achieved the level of prominence of other disorders in geriatric psychiatry, such as Alzheimer's disease and major depression, and thereby remain underrecognized and undertreated. In addition, elderly individuals with anxiety often present to medical attention with comorbid depression as the primary focus for referral and treatment. Most anxiety disorders begin earlier in life, recurring over decades, and if an individual has not sought treatment for the condition previously, it is less likely that he or she will enter the mental health system at this stage. In addition, due to life circumstances, it may be easier for the elderly to conceal their anxiety by avoiding anxiety-provoking situations, such as those that could arise in work, school, or other social settings. Anxiety is underrecognized not only by geriatric health-care providers, but also by elderly patients, who tend to have greater difficulty identifying symptoms of anxiety. Thus, proper recognition of anxiety disorders is further complicated by the unique presentation of anxiety in the elderly, as well as by inadequate instruments for assessment and diagnosis and confounding effects of psychiatric and medical comorbidity in this population.

The differential diagnosis for anxiety in the elderly is broad, as presented in **Table 2**. Anxiety may present as a primary anxiety disorder or as a symptom secondary to another mental disorder, a physical illness, or a medication side effect or drug interaction.

Anxiety Secondary to Another Mental Disorder

Anxiety is a symptom commonly seen with dementia, major depression, and hypomania. For example, 60%

Table 2 Differential diagnosis of anxiety disorders in the elderly

Primary anxiety disorders	Generalized anxiety disorder Obsessive-compulsive disorder Panic disorder Agoraphobia Post-traumatic stress disorder Social anxiety disorder Specific phobia
Anxiety secondary to another mental disorder	Dementia, with agitation Major depression, with agitation Bipolar disorder, hypomania Alcohol abuse or dependence, with intoxication or withdrawal
Anxiety secondary to a medial condition	Hypoxia or ischemia Cardiac arrhythmias Congestive heart failure Pheochromocytoma Hyper/hypothyroidism Hypoglycemia B12 deficiency Alcohol withdrawal Parkinson's disease Primary sleep disorder Delirium of any cause
Anxiety secondary to medications	Amfetamines Anticholinergics Antidepressants/SSRIs (initiating; discontinuation) Antipsychotics B-agonists Benzodiazepine withdrawal Caffeine-containing products Herbal supplements: ginseng, ephedra, mahuang, guarana Sympathomimetics (including over-the-counter cold remedies containing pseudoephedrine) Thyroid medications Vasopressors

of patients with dementia at some point experience agitation that may be difficult to distinguish from anxiety or that may co-exist with anxiety, potentially important distinctions when considering treatment options. Factors to consider in distinguishing between anxiety and agitation include onset (acute vs. chronic), acuity, course, cognitive status, and underlying medical morbidity. In contrast to anxiety, agitated patients may also exhibit loss of impulse control that can result in disruptive and inappropriate behavior.

As noted earlier, anxiety with comorbid depression is the most common presentation of anxiety in the elderly. This presentation tends to be associated with a more severe depressive illness, more suicidality, and poorer treatment outcome, with delayed or diminished response and greater likelihood of treatment non-adherence and dropout. The treatment team plays an important role in optimizing treatment outcome in this situation, as the quality of clinical management has been found to have the greatest impact on the likelihood of remission in elderly with anxious depression.

Problem drinking is also important to consider in the differential diagnosis for anxiety in the elderly. As many as one-third of older adults with alcohol use problems develop the problem after age 60, and this misuse of alcohol may serve as a form of self-medication for their anxiety. It has been suggested that alcohol abuse in the elderly is substantially underdiagnosed, in part because the effects of alcohol use in this population may be less visible than in younger age groups and the elderly may be less likely to seek treatment. Underrecognition has significant clinical implications in the elderly due to the risks associated with alcohol abuse and relapse, both of which may occur in the setting of anxiety, interpersonal conflict, loss, social isolation, loneliness, and depression.

Anxiety Secondary to a Medical Condition

Anxiety is a common manifestation of a wide variety of physical illnesses, as noted in **Table 2**. With changes in multiple organ systems with aging, older adults are more likely to experience one or more of these conditions over time, placing them at increased risk for experiencing anxiety symptoms. Acute onset of anxiety in the elderly needs to be carefully assessed to determine whether an underlying treatable medical condition is present.

Anxiety Secondary to Medications

Another important consideration is concomitant medication use, including prescription drugs, over-the-counter medications, herbs and dietary supplements, and, less commonly, illicit drugs. Commonly used drugs and supplements that may be associated with symptoms of anxiety are noted in **Table 2**. It is important to remember that older adults tend to be more sensitive to both the therapeutic and toxic effects of pharmacological agents. In addition, many individuals in this age group are taking multiple medications, and the risk of drug interactions increases exponentially with polypharmacy. Treatment non-adherence should also be considered; medication misuse may be due to cognitive impairment, lack of understanding of dosing instructions, or intentional non-adherence. Last, the elderly are among the largest consumers of herbs and supplements, and they may be reluctant to disclose this use to their

doctors or not consider them of importance unless asked specifically about them. Many of these products are pharmacologically active (such as ginseng), and health-care providers need to be aware of patients' use of these agents when prescribing medications.

Treatment of Anxiety in the Elderly

Empirically validated knowledge about appropriate interventions for anxiety in the elderly is sparse. Inferences from data in younger adults typically form the basis for clinical practice in the elderly.

Management of anxiety disorders includes both non-pharmacological and pharmacological treatment. Selection of treatment should include assessment of individual risks and benefits, considering medical and psychiatric comorbidity, patient preference, cost, and availability of resources (e.g., trained therapists). A number of cognitive and behavioral therapies have been shown to be effective in treating anxiety disorders, such as cognitive-behavioral therapy (CBT), exposure therapy for specific phobias and compulsive behaviors, and even psychodynamic therapies (though the empirical evidence is sparse for these therapies). If medications must be avoided, then these approaches become the only viable therapies and should be made available to older adults. In general, when the logistics can be worked out, older adults are both willing to participate in these therapies and cooperative. In addition, anxiety symptoms can also improve with regular exercise, with gains comparable to what is observed with relaxation and meditation. Acute anxiety tends to respond better to exercise than chronic anxiety. However, any recommendations for exercise should be made in the context of the patient's physical health.

Pharmacological therapy must be prescribed with caution. The clinician must monitor for drug interactions and adverse side effects. For most medications, the side effects are more common in late life. Therefore, the clinician must begin therapy with a low dose and monitor the drugs carefully. Anxious patients often misattribute somatic symptoms of anxiety to medication side effects, which can impact on treatment adherence. If the older adult tolerates the medication yet does not respond, then the dose can gradually be increased. Clinicians can greatly augment the monitoring of these medications by maintaining phone contact with the patient or family members. Frequently a 5-min phone call can prevent an ongoing side effect from leading to more serious adverse outcomes (such as a fall) as well as prevent an office visit and enhance treatment adherence.

Antidepressants

Antidepressants are considered the first-line pharmacotherapy for anxiety disorders, with the advantage of treating symptoms of both anxiety and comorbid depression. Among the antidepressants, the serotonergic drugs (selective serotonin reuptake inhibitors [SSRIs] and serotonin norepinephrine reuptake inhibitors [SNRIs]) are widely considered the first choice. While very limited empiric data are available regarding their effect on anxiety in older adults, these drugs have demonstrated generally good tolerability in geriatric depression. Notably, some concern has been raised regarding possible cardiovascular side effects with the SNRIs in light of reports of possible impaired heart rate variability with these drugs.

Both the SSRI and SNRI drugs can be anxiogenic, particularly when initiating treatment, and it is important to discuss this possibility with the patient, along with the goal of minimizing these effects by starting at a low dose and titrating accordingly. The clinician also needs to be mindful that these medications can be associated with discontinuation symptoms when stopped abruptly. While not life threatening, these symptoms may be anxiety provoking for some individuals, especially those predisposed to anxiety, and it is important to have a dialogue with the patient about the importance of treatment adherence. Should the time come to discontinue the drug, this can be done safely by tapering the medication over several weeks under medical supervision.

While the older classes of antidepressants have demonstrated efficacy in depression and anxiety, their multiple side effects and medication and dietary interactions have relegated them to second- or third-line use in the elderly. For example, the tricyclic antidepressants, while effective, can be associated with significant toxicity, particularly anticholinergic, cardiovascular, and histaminergic effects, which may be particularly troublesome for older adults. The monoamine oxidase inhibitors are also associated with poor tolerability as well as significant medication interactions and dietary restrictions that limit their use.

Benzodiazepines

The benzodiazepines constitute the most widely used symptomatic treatment of anxiety and insomnia in adults and are disproportionately prescribed in the elderly. Among the groups most likely to use these drugs on a continuous basis are elderly with comorbid medical and psychiatric problems, elderly taking multiple medications, and elderly women, groups that may also be more likely to experience adverse effects with treatment. In the short term, these drugs

cause cognitive and psychomotor impairment, placing users at greater risk for falls and other accidents. Longer-term use can be associated with physiological dependence and withdrawal.

Given these considerations, these drugs in the elderly are recommended primarily for short-term use. However, it should be noted that some older adults may benefit from extended, continuous use of benzodiazepines in a safe and carefully monitored setting. Further research is needed to identify individuals who will benefit from intermittent vs. continuous treatment, while minimizing risk of toxicity.

Buspirone

The 5HT partial 1A agonist buspirone is an anxiolytic drug that has demonstrated efficacy in adults with GAD and may be of particular utility in the elderly. The drug is generally better tolerated than the benzodiazepines, without sedation or psychomotor impairment, dependence, or withdrawal, and it does not potentiate the effects of alcohol. The primary disadvantages of the drug are a delayed onset of action, over several weeks, and the need for dosing several times a day.

Antipsychotics

Antipsychotics are most widely used to treat agitation and psychosis in the elderly, with almost no empiric data to support their use in geriatric anxiety. Of the first-generation antipsychotics, haloperidol is the most widely prescribed, with fairly good tolerability in low doses, though at higher doses concerns are raised about possible extrapyramidal, cardiovascular, and anticholinergic effects. While initially favored for treating agitation in dementia with delusional ideation, the atypical antipsychotics have also drawn attention regarding possible increased mortality rates in the elderly. In general, experts do not recommend the use of atypical antipsychotics in older adults with GAD or panic disorder.

Other Drugs

Several other medications have demonstrated anxiolytic effects in older adults. For example, propranolol may be helpful in reducing autonomic symptoms associated with anxiety (i.e., tachycardia, palpitations, trembling) but does not help with psychic anxiety and worry and should be avoided in those with asthma and a propensity to hypotension. Antihistamines (e.g., diphenhydramine, hydroxyzine) may also be helpful for intermittent or more extended use, but patients need to be monitored for sedation and mucosal anhydrosis.

Summary

Given these considerations, we note the following needs for the future to facilitate the proper diagnosis and treatment of anxiety in the elderly:

- Conclusions drawn based on data from younger populations of adults may not hold true for the elderly. Studies of the phenomenology and treatment of geriatric anxiety are needed.
- Traditional diagnostic and treatment approaches may not be suitable for the elderly; a multidisciplinary perspective may be more appropriate. A comprehensive assessment of anxiety symptoms requires consideration of physical, intellectual, emotional, environmental, and social determinants.
- The anticipated growth of the population of older persons with mental disorders underscores the need for a strategy to facilitate systematic and effective implementation of evidence-based practices in geriatric mental health care.

See also: Depression; Disability, Functional Status and Activities of Daily Living; Mental Health; Pharmacology; Psychological Well-Being.

Further Reading

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Arthritis and Rheumatic Diseases

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Glossary

Arthritis – A general term encompassing over 100 types of diseases that involve joint pain and inflammation.

Cyclooxygenase-2 Inhibitors (Coxibs) – New class of medications with action similar to non-steroidal anti-inflammatory drugs (NSAIDs) but with fewer gastrointestinal side effects.

Musculoskeletal – System of the body comprising the bones, cartilage, ligaments, tendons, and joints.

Non-steroidal Anti-inflammatory Drugs (NSAIDs) – Non-narcotic and non-steroidal drugs used to treat pain and suppress inflammation in a variety of conditions.

Introduction

Arthritis is a major cause of morbidity and disability, particularly in older individuals. Strictly speaking, the term arthritis means inflammation of the joints. However, the terms arthritis and rheumatism are often used interchangeably to encompass disorders of the joints, ligaments, tendons, and other components of the musculoskeletal system. Arthritis and rheumatism comprise more than 100 different conditions, amounting to more than half of the conditions included in the larger classification of musculoskeletal disorders (MSDs). Other conditions in the larger family of MSDs are back disorders not associated with arthritis and metabolic bone disorders such as osteoporosis. These are not covered in this article.

Background

The symptoms and signs of arthritis and related conditions include pain, stiffness, swelling, muscle weakness, and limitation of movement of the joints. These are some of the most common health complaints among older people. Together these symptoms and signs greatly affect the population in terms of morbidity, disability, and cost. Traditionally, the burden of arthritis in the population has been underestimated. With the aging population, however, the impact of arthritis is becoming increasingly apparent. Arthritis is one of the leading causes of pain, physical disability, and health-care utilization in Canada. According to the 2000 Canadian Community Health Survey (CCHS), rheumatic conditions affect almost 4 million Canadians over the age of 15, with nearly 40% of these over the age of 65. By the year 2026, over 6 million Canadian adults are expected to suffer from arthritis and related conditions. In the United States, it have been estimated that 27% of the population have physician-diagnosed arthritis.

The frequency of arthritis increases with age. However, older people may often fail to seek care for symptoms because these conditions are considered by many to be a normal part of aging. Complaints pertaining to arthritis are often vague and ill defined, and may be associated with insidious decline in overall function. Pain is the most common symptom in rheumatic disease patients consulting a physician, and this may be misinterpreted due to the presence of other conditions, including depression.

Diagnosis and management of arthritis can be particularly challenging in the elderly. Musculoskeletal symptoms can also be caused by other conditions, and multiple conditions in the same patient may complicate both diagnosis and management. Unfortunately, there is no one simple diagnostic test to confirm a diagnosis of arthritis. Often a combination of radiological and laboratory testing is required in addition to clinical assessment. In addition, the prevalence of many autoantibodies (such as rheumatoid factor) and inflammatory markers (e.g., erythrocyte sedimentation rate [ESR]) increases in the elderly, leading to difficulty with interpretation of test results. Management of arthritis in the elderly also has unique challenges. Issues such as use of multiple medications, comorbid conditions, and altered pharmacokinetics must be considered when determining treatment. Clinical trials for new therapeutics have largely excluded older patients and those with multiple medical problems, leading to further difficulty for management of arthritis in the elderly.

It is not possible to review all of the different types of arthritis and related conditions here. In this article, we describe the clinical characteristics, epidemiology, and management of selected types of arthritis, indicating, whenever possible, any special considerations that might apply to the older population. A comparison of the major clinical findings of five common types of arthritis in the elderly is provided in **Table 1**. The article concludes with a discussion of the overall impact of arthritis in seniors and general management strategies to reduce the impact of arthritis in the elderly population.

Table 1 Clinical aspects of common rheumatologic disorders in the elderly[a]

Disorder	*Osteoarthritis*	*Rheumatoid arthritis*	*Polymyalgia rheumatica*	*Gout*	*Pseudogout*
Gradual onset	+ + +	+ + +	+ + +	0	+
Joint swelling or effusion	+ + +	+ + + +	+	+ + + +	+ + + +
Joint pain	+ + + +	+ + + +	+	+ + + +	+ + + +
Symmetrical involvement	+	+ + +	+ + + +	+	+
Muscle pain	+	+	+ + +	+	+
Radiographic abnormalities	+ + + +	+ + +	0	+	+ + +
Synovial fluid crystals	+	+	0	+ + +	+ + +
Elevated sedimentation rate	+	+ + +	+ + + +	+	+
Anemia	0	+ +	+ + +	0	0
Positive antinuclear antibody	0	+	+	0	0
Positive rheumatoid factor	0	+ + +	+	0	0

[a]0, does not occur; +, occurs occasionally; + +, occurs frequently; + + +, almost always occurs; + + + +, difficult to make diagnosis without it.
Adapted from Table 8-5 in Kane RL, Ouslander JG, and Abrass IT (1983) *Essentials of Clinical Geriatrics*. McGraw-Hill Book Company.

Types of Arthritis in the Elderly

Osteoarthritis

Clinical Features In addition to being the most common type of arthritis in humans, osteoarthritis (OA) is also a major health problem in dogs, horses, and many other animals. Skeletal remains going back to prehistory show signs of osteoarthritis. Despite its high prevalence in the population and its importance as a cause of pain and disability, OA is less well understood than many of the other rheumatic disorders. Traditionally, OA has been thought of as a disease related to aging, with 'wear and tear' of the joint leading to loss of joint space and remodeling of bone. New insight into the disease suggests that it is a heterogeneous disease with multiple factors such as crystal deposits in the joints and inflammation contributing to disease progression. OA can occur without any obvious predispositions, or it can result from a previous injury or disease of a joint that may have occurred many years earlier.

The most common symptom of OA is pain, most often related to joint use. Pain can also occur at rest and at night. Stiffening or 'gelling' of joints in the morning or after prolonged periods of inactivity is common in OA, and often resolves within minutes of resuming activity. The stiffness associated with other types of arthritis such as rheumatoid arthritis is different and can often last for hours. Although OA is not primarily inflammatory, OA can result in swelling and warmth of the affected joint. In OA, range of motion of the joints is often restricted, with pain and limitation of movement at the end of range. Over time, this may result in atrophy of the muscle surrounding the joint, bony deformities, and disability. OA may affect one or many joints of the body, most typically the knees, hips, hands, big toes, and the spine. The joints most commonly involved in OA are shown in **Figure 1**. In all joint sites except the hip, OA is more common in women than in men. An important distinguishing feature of OA is that shoulders, elbows, wrists, and ankles are seldom affected, as they are in types of inflammatory arthritis such as rheumatoid arthritis. OA is slow to evolve, and often has periods of relative stability lasting many years. Rapid progression can occur, and

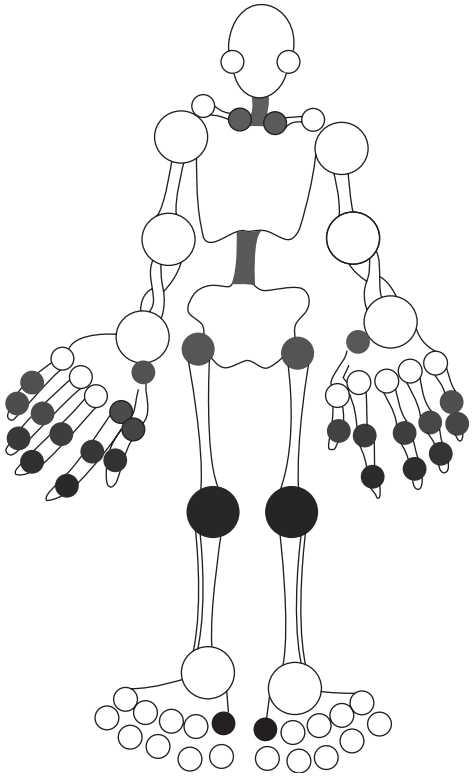

Figure 1 Black shading indicates those joints most often affected in osteoarthritis. (From Figure 1, Cooke TDV and Dwosh IL (1986) Clinical features of osteoarthritis in the elderly. *Clinics in Rheumatic Diseases* 12(1): 155–172.)

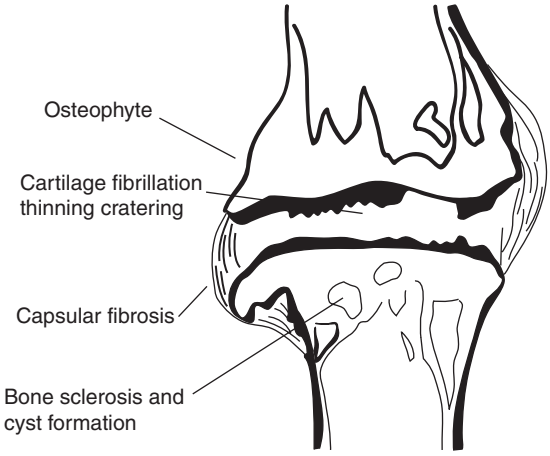

Figure 2 Pathological features of osteoarthritis. (From Figure 1, Hutton CW (1995) Practical problems: osteoarthritis—clinical features and management. In: Butler R, Jayson M, McKenna F, and Scott D (eds.) *Reports on Rheumatic Diseases*. Chesterfield: Arthritis and Rheumatism Council.)

spontaneous improvement is a rare but well-described phenomenon.

The hallmark findings of OA on plain X-ray include joint space narrowing due to loss of articular cartilage, remodeling and patchy thickening of bone (sclerosis), areas of bone loss beneath the cartilage (subchondral cysts), and formation of bony spurs (osteophytes). **Figure 2** illustrates the typical changes that can occur with OA. Diagnosis of OA can be difficult for a variety of reasons, one being that there is no clear diagnostic marker. Although many biomarkers have been investigated, their clinical use is limited by variability in test results for individual patients. While there is some agreement between the clinical and radiographic findings in OA, there is no consistent correlation between the two. Some patients will have severe radiographic findings with few clinical symptoms, while other patients display severe clinical symptoms and minor radiographic changes. Increased use of ultrasound and magnetic resonance imaging (MRI) may help to improve the correlation between radiographic and clinical tests in the future.

Epidemiology and Risk Factors OA is the most frequently occurring type of arthritis in the population. Very little data exist measuring the incidence of OA in the population, as there are problems in defining the disease onset and a lack of longitudinal data. Age seems to be one of the most important risk factors for the disease, as incidence increases with age. The prevalence of OA in the population over 65 years of age ranges from 33% with symptomatic OA to more than 80% with radiographic OA. In the United States, OA is the second highest cause of work disability in men over the age of 50. It has been found to disable 10% of people over the age of 60.

Risk factors for OA are those related to a generalized susceptibility to the disease and to mechanical factors resulting in abnormal biomechanical loading of joints. Susceptibility to OA has been found to be related to increased age, obesity, heredity, low socioeconomic status, and female gender. There are marked racial differences in prevalence and joint distribution. Trauma to the joint, joint incongruence, and occupational or leisure physical activities that involve repetitive motion have been associated with the development of OA. Osteoporosis, particularly in the hip joint, has been shown to be protective against osteoarthritis.

Management There are many challenges in the treatment of elderly patients with OA. Patients and family members often dismiss it as an inevitable part of aging for which nothing can be done. Furthermore, patients and caregivers may believe that it is best to be inactive to protect joints – a strategy that can have detrimental consequences. Finally, comorbidities and use of multiple medications can lead to difficulties with pharmacologic therapy.

The management of OA is largely symptomatic. Its objectives include relief of pain and stiffness, minimization of disability, maximization of function, and reduction of progression. Treatment can be divided into non-pharmacologic, pharmacologic, and surgical. Ideally, a hierarchical cumulative approach to management of OA should be used, encompassing both non-pharmacologic and pharmacologic treatments. All patients should receive education, counseling, and dietary advice if overweight. For those with more severe OA, teaching about joint protection may be required along with assessment of level of function and disability. Shoe alterations, braces, and walking aids can help alleviate problems of biomechanical origin, and assistive devices may improve function. Weight loss, physical therapy for muscle strengthening, and exercise are important components of a treatment program for individuals with hip and knee disease. There has recently been increased interest in acupuncture as a treatment modality for OA. Studies have found acupuncture effective for reducing pain and improving function for patients with knee OA.

Pharmacologic treatment includes analgesics, nonsteroidal anti-inflammatory drugs (NSAIDs), cyclooxygenase-2 inhibitors (Coxibs), intra-articular steroids, viscosupplementation (an injection to help lubricate the joint), and nutraceutical products.

Studies have demonstrated that for OA of the knee, simple analgesics such as acetaminophen, codeine, and low-dose salicylates can result in clinically important relief of symptoms. Analgesics may be an excellent choice for individuals with multiple medications and mild symptoms. Local applications that include NSAIDs have been developed. These and other rubs have been shown to be beneficial in some cases, without systemic toxicity. Oral NSAIDs remain the mainstay of treatment for OA. Their use in the elderly population, however, has been brought into question. Changes in the metabolism of older people, particularly kidney and liver function, may lead to potentially serious or even lethal side effects when drugs are taken in full doses. Adverse events, such as gastrointestinal bleeding, may be silent or asymptomatic and may eventually lead to a major medical emergency. As a general principle, it is recommended that elderly patients receive a reduced dose. There has been debate in the literature as to whether acetaminophen or NSAIDs should be the first choice for treatment. This decision needs to be made clinically, taking into consideration the severity of symptoms and risk factors for the medications. Alternatively, they can also be used in combination. The more recently available Coxibs have potential as safer therapy with decreased risk of serious gastrointestinal toxicity. However, these have been associated with cardiovascular and cerebrovascular risk. It is important, therefore, to carefully weigh the risks and benefits of treatment before initiation. Intra-articular steroid injections may provide relief of pain and swelling, especially if there is one predominantly symptomatic joint. These are only good for temporary symptom relief, however, and should not be given more than three times a year per joint. Viscosupplementation with intra-articular hyaluronic acid (HA) may be an option for patients who do not respond to other treatments. There is some evidence that HA may improve pain in patients with knee OA.

The nutraceuticals glucosamine and chondroitin have been found to be effective for the treatment of OA. Chondroitin is a protein that helps give the joint elasticity, while glucosamine sulfate is a type of sugar that helps cartilage formation and repair. Studies have shown that both of these substances may be effective in symptom control at doses of 1500 mg daily of glucosamine and 800 mg daily of chondroitin. In general, patients should be encouraged to try these substances at recommended doses for 3 months. At this point, if there is no improvement in symptoms, then they will likely not be effective in the future and should be discontinued. Patients should also be encouraged to carefully read labels when buying over-the-counter preparations, as there is wide variety in the content of glucosamine and chondroitin in different products.

In advanced cases, surgery may be indicated. Indications for surgery include uncontrolled pain, particularly pain at rest and pain at night, and limitations in performing activities of daily living. Surgical techniques include realignment of joints by osteotomy (the cutting and repositioning of parts of the bone), chondrocyte grafting to resurface damaged cartilage, and joint replacement surgery. Total hip and total knee replacements are well-established procedures and frequently result in dramatic relief of pain and improvement of function. Joint replacement prostheses have a limited life (around 20 years), but this is not a contraindication in the older individual.

Gout

Gout is the most common kind of crystal-induced arthritis. The types of crystal arthritis have in common the finding of microscopic crystals in the tissues or synovial fluid of the joint. The crystals are believed to play a role in the inflammatory process of the disease.

Clinical Features Gout occurs when uric acid crystallizes in the joints, causing intense inflammation. The joint is typically hot, red, swollen, and extremely painful. Attacks of gout are usually acute, self-limited episodes of monoarthritis (arthritis in one location) but may be polyarticular (affecting many joints) and chronic. The initial attack usually occurs after years of asymptomatic hyperuricemia (high blood urate levels) and it only affects one joint in 85–90% of patients. Attacks frequently affect the lower extremities and last from a few days to 3 weeks. The big toe is the most common site, but almost any joint in the body can be affected. Patients are usually asymptomatic between attacks. Over years, attacks occur more frequently, last longer, may become polyarticular, and may be associated with systemic symptoms including fever. Chalky deposits called tophi may occur under the skin, and chronic polyarthritis may develop. In the elderly, gouty arthritis is more difficult to diagnose as it has a number of features that are different than gout found in younger patients. For example, in older patients, polyarticular gout involving the small joints of the fingers is more common, especially in women. Additionally, in the elderly, tophi often occur earlier and in atypical areas. Attacks of gout are commonly associated with diuretic use and renal insufficiency. Gouty arthritis can be misdiagnosed as OA and even RA, and this

can be further complicated as occasionally gout and OA coexist, even in the same joints.

Epidemiology and Risk Factors Gout is the most common cause of inflammatory arthritis in men over the age of 40, with a peak incidence in the fifth decade. The peak incidence for females occurs over the age of 60. It is difficult to determine incidence and prevalence rates of the disease, as the course of the disease is characterized by exacerbations and remissions, and there is also a tendency for misdiagnosis by both patients and clinicians. Estimated prevalence for self-reported gout in the general population is 0.7–1.4% in men and 0.5–0.6% in women. This is higher in adults over 65, with prevalence of 4.4–5.2% in men and 1.8–2.0% in women. Studies of gout over the past two decades suggest increasing incidence, especially in the elderly population.

It has been estimated that gout is the second most common form of inflammatory arthritis in the United States. It occurs worldwide, and regional differences may reflect racial predisposition, although this has not been proven. Gout frequently results in occupational limitations, increased use of medical services, and significant short-term disability, making the disease a significant public health problem.

The epidemiology of gout appears to be changing. Studies of temporal trends have indicated increases in prevalence over the last few decades in several countries with high standards of living. The sex ratio has also changed. The ratio of males to females with gout was previously 20:1 but has recently been estimated at 2–7:1. It has been suggested that these changes are related to the use of medications (particularly thiazide diuretics), increased longevity, and changes in lifestyle.

Risk factors for gout are varied. Plasma urate concentration is directly related to the risk of developing gout. Hyperuricemia can be due to decreased renal excretion or overproduction of uric acid. In the majority of individuals, it is related to underexcretion. The risk of developing gout is similar in males and females for particular urate concentrations, and the lower prevalence of gout in females is likely indicative of lower urate concentrations. Urate concentrations are highly age dependent, with levels increasing with age. There appears to be a genetic predisposition to the disease, as gout is associated with inherent enzyme abnormalities and inherited urate underexcretion. Environmental factors are also important. The risk of gout is increased with diets rich in meats, seafood, and alcohol. Medication use, including thiazide diuretics, low-dose aspirin, and cyclosporine, and toxin exposure (e.g., lead) has been associated with hyperuricemia and the development of gout.

Management Management of gout includes treatment of acute attacks and prevention of recurrent attacks. For acute episodes, treatment options include local cortisone injection, a short course of systemic steroids, NSAIDs (particularly indometacin), Coxibs, and colchicine. Colchicine is rarely used alone for the treatment of acute attacks due to gastrointestinal side effects. Patients with more than three gouty attacks in 1 year, tophi, polyarticular disease, and gouty nephropathy may benefit from long-term therapy (hypouricemic therapy) to lower the level of uric acid in the blood and prevent future attacks. The most commonly used medication for hypouricemic therapy is allopurinol, a xanthine oxidase inhibitor. However, allopurinol should never be used during an acute attack because there is a risk of triggering an attack with the onset of treatment. For this reason it is often initiated with low-dose colchicine in the first few months for prophylaxis. Uricosuric drugs such as allipurinol are seldom used in elderly patients, as they are often poorly tolerated and may have decreased efficacy.

Calcium Pyrophosphate Deposition Arthropathy (Pseudogout)

Clinical Features Calcium pyrophosphate deposition arthropathy is a further kind of crystal-induced arthritis. There is a broad spectrum of diseases associated with calcium pyrophosphate dehydrate deposition disease (CPPD or pseudogout). Included in this category are asymptomatic chondrocalcinosis, acute monoarthritis (pseudogout), and clinical presentations mimicking OA (pseudo-osteoarthritis), rheumatoid arthritis (pseudorheumatoid arthritis), and neuropathic joint disease. In CPPD, inflammation is induced by the presence of crystals of calcium pyrophosphate in the joints. The most common clinical presentations include acute mono- or polyarthritis, chronic arthropathy, and asymptomatic radiographic findings. In pseudogout, at least 50% of attacks are in the knees, but the shoulders, wrists, and ankles may also be affected. Although not as painful or intense as gout, acute monoarthritis due to CPPD is just as common. It is often seen in individuals with preexisting OA and is commonly precipitated by trauma or acute medical illness.

Epidemiology and Risk Factors CPPD arthropathy occurs most often in aging females. The mean age of onset is between 65 and 75 years. It is estimated to affect 10–15% of individuals between 65 and 75 years of age and more than 40% of individuals over age 80. CPPD has been reported throughout the world. There appears to be familial aggregation that

has shown an autosomal dominant transmission pattern, involving single gene mutations. There is also an association with endocrine and metabolic diseases including hyperparathyroidism, hypophosphatasia, hypomagnesemia, and hemochromatosis. CPPD arthropathy appears to be linked with aging of the articular cartilage, although the nature of this relationship has not been clarified. Most cases of CPPD have no known cause.

Management The goals of treatment are to reduce symptoms, identify and treat any triggering illness, and rapidly mobilize the patients as inflammation settles. Rapid mobilization is important, as older patients are prone to complications from prolonged immobility. In many cases, joint aspiration to remove synovial fluid from the joint may be the only treatment required. An intra-articular steroid injection may be appropriate for a joint that does not settle after the first aspiration. Analgesic and anti-inflammatory drugs may provide additional benefit when used with caution in elderly patients. NSAIDs, colchicine, physiotherapy, and education can all help to reduce pain associated with CPPD. For patients with rheumatoid-like disease, there may be some benefit from the use of hydroxychloroquine, an antimalarial medication with anti-inflammatory properties. Surgery such as total joint replacement may be necessary in the presence of advanced joint degeneration.

Rheumatoid Arthritis

Clinical Features Rheumatoid arthritis (RA) is one of the most common autoimmune diseases. It typically begins as symmetrical pain and swelling of the small joints of the hands and feet, along with stiffness in the morning that can last for several hours. The disease is typically accompanied by fatigue, anorexia, and weight loss. **Table 2** compares the characteristics of RA and OA.

Older RA patients fall into two categories: patients who have suffered from chronic RA for many years or even decades and patients with recent or new onset of disease. Patients with established disease may still have active disease, or may be burnt out but still have symptoms because of damage and deformities in joints previously affected by RA. Disease onset is often acute, with disabling morning stiffness, limited range of motion, severe soft tissue swelling, and marked elevations in inflammatory markers. Involvement of the large joints, especially the shoulders, is common along with involvement of wrists, and metacarpophalangeal (MCP) joints and proximal interphalangeal (PIP) joints in the hand. Extra-articular manifestations of the disease (such as vasculitis) occur less often in the late-onset patient. Laboratory tests for the diagnosis of RA may be different in the elderly. For example, rheumatoid factor, an antibody that recognizes the Fc portion of the IgG molecule, increases with age, and so may be less useful for diagnosis. Furthermore, elevations in inflammatory markers (including ESR and C-reactive protein) may be misleading in the elderly, in whom they may be elevated due to comorbid conditions or due to aging itself. This combination of factors can make the diagnosis of RA in the elderly extremely challenging.

The course of RA is unpredictable. In some cases, late-onset RA has been found to have a more favorable outcome than younger-onset RA, while in other cases, the prognosis is worse. The majority of patients will experience intermittent periods of active disease alternating with periods of relative or complete remission. A minority may have complete remission, but a small group of patients will have severe, unrelenting, progressive disease. Irreversible joint deformities may also characterize the physical findings of people with long duration and greater severity of disease. These deformities may lead to difficulties in walking and with activities of daily living (ADLs) and result in significant functional disablement. RA is an important cause of disability.

Epidemiology and Risk Factors The peak onset of RA is midlife, although the prevalence of RA increases with age up to approximately age 85. The

Table 2 Clinical features of osteoarthritis versus inflammatory arthritides[a]

Clinical features	*Osteoarthritis*	*Inflammatory arthritides*
Duration of stiffness	Minutes	Hours
Pain	Usually with activity	Occurs even at rest and at night
Fatigue	Unusual	Common
Swelling	Common, but little synovial reaction	Very common with synovial proliferation and thickening
Erythema and warmth	Unusual	Common

[a] Osteoarthritis may also be inflammatory.
From Table 8-6 in Kane RL, Ouslander JG, and Abrass IT (1983) *Essentials of Clinical Geriatrics*. McGraw-Hill Book Company.

prevalence of RA in the population over 60 years of age is reported to be 2%, double the prevalence in the general population (1%). The sex ratio of RA varies with age. The disease affects mainly females under the age of 60, but over age 60 the sex ratio is much more equal.

Although the cause of RA is unknown, many risk factors, genetic, hormonal, and environmental, are associated with its development. The risk of developing RA is 1.5 times higher if a first-degree relative also has RA, and in twin studies, the concordance for monozygotic twins was 12–15% while that in dizygotic twins was 3.5%. The development of RA has been associated with certain alleles of major histocompatibility complex class II including HLA-DR4, HLA-DR-1, and DR-14. Other genes have also been found to play a role. Aside from genetics, hormones and environmental factors have been implicated. Increased risk of RA has been associated with nulliparity in women and low testosterone levels in men. Pregnancy is associated with remission, while menopause is a common time of symptomatic onset of RA. Decreased risk is associated with breast-feeding and oral contraceptive use. Infections, including bacterial and viruses, may contribute to risk of RA. Thus, it appears that a range of genetic, hormonal, and environmental factors can influence the development of RA.

Management Treatment of RA focuses on decreasing pain, swelling, and stiffness, improving function, and preventing damage and disability. The mainstay of treatment for RA in the elderly is medication, which is similar to that in the younger patient, with the caveat that adverse drug reactions may be more likely. Classically, physicians have followed the pyramid approach when selecting drugs for the treatment of RA. This involves starting with NSAIDs and using more potent drugs as required. The pyramid approach to treatment is no longer accepted, however. Studies have shown that joint damage occurs early in the disease. Furthermore, early and aggressive treatment has been found to prevent disability many years later. There is thought to be a 'window of opportunity' early in the disease, when RA is more responsive to immunosuppressive treatment. In addition, combination therapy with two or more agents has consistently been found to be superior to monotherapy. Therefore, current recommendations include early and aggressive treatment with combination therapy. Disease-modifying antirheumatic drugs (DMARDs) are used to prevent progression of disease for patients with RA. These drugs take several months for clinical response and carry a risk of serious adverse effects. Therefore, their use needs to be carefully monitored under the supervision of a physician experienced in the treatment of RA. Corticosteroids may also have a place in treatment, either systemically in low doses or injected into inflamed joints to reduce inflammation. Over the past few years, biologic therapeutic agents have been introduced and used for the treatment of RA. These are an alternative for patients not responding to traditional DMARDs. NSAIDs and Coxibs can also be used, with caution, for symptom control. Physiotherapy to treat pain and swelling and maintain range of motion and function is often an excellent adjunct to medical therapy.

Surgical treatment may be recommended for RA patients to relieve unresolved pain, loss of function, and deformity. Joint replacements of hips and knees, tendon repairs, and carpal tunnel releases are some of the more frequently employed measures in the elderly. Age itself is not a contraindication for surgery, nor is it a predictor of poor results.

Polymyalgia Rheumatica

Clinical Features Polymyalgia rheumatica (PMR) is a clinical syndrome of middle-aged and elderly people characterized by pain and stiffness in the neck, shoulder, and pelvic girdles, often accompanied by constitutional symptoms such as fever, fatigue, anorexia, and weight loss. Stiffness is the predominant feature and is particularly severe after rest. In extreme cases, the stiffness may prevent the patient from getting out of bed in the morning. Muscular pain is often diffuse and is accentuated by movement. Pain at night is common.

Epidemiology and Risk Factors PMR is a condition of the older patient. It is seldom diagnosed under the age of 50. The mean onset of PMR is approximately 70 years, with a range of about 50–90 years. Women are affected two to three times more often than men. It is difficult to determine prevalence and incidence of the disease, as there is a lack of specific signs and symptoms. In older persons, its estimated prevalence approaches 1% and the annual incidence rate has been estimated at 13 to 113 per 100 000 individuals over age 50. Incidence varies by geography.

There appears to be a genetic predisposition to the disease, as evidence exists for familial aggregation. Environmental factors may also be important, as there is clustering of cases in time and place. The greatest majority of patients are Caucasian, and the disease appears to be more common in the northern United States, Canada, and Europe, compared to southern regions.

PMR has been associated with giant cell arteritis (GCA). Symptoms typical of GCA include headache, scalp tenderness, jaw pain on chewing, and visual changes. Approximately 15% of patients with PMR will go on to develop GCA, while almost 50% of patients with GCA will have concurrent PMR. It is important to rule out GCA in PMR patients, as if left untreated, it can lead to irreversible blindness. For definitive diagnosis of GCA, temporal artery biopsy should be performed.

Management Of the forms of arthritis affecting the elderly, PMR is one of the most difficult and important to diagnose. The main treatment is systemic corticosteroids. Patients have a dramatic response to even small doses of prednisone, a corticosteroid. In fact, administration of low-dose prednisone is often used as a diagnostic test in patients with vague complaints. There is no universally accepted approach to initial corticosteroid therapy, maintenance, or dose reduction. Once symptoms have resolved and inflammatory markers have normalized, the dose of steroid may be slowly tapered. During tapering, inflammatory markers should be assessed regularly. If there is recurrence of symptoms or increase in markers, the steroid dose should be increased accordingly. Patients will generally require treatment for up to 2 years. Patients should be counseled regarding the side effects of prolonged steroid use. Regular assessment of blood pressure, blood sugar, and bone density should be done while on therapy. Bone protection with calcium, vitamin D, and bisphosphonate should be considered. Patients with concurrent GCA will require higher doses of prednisone along with appropriate monitoring.

Impact of Arthritis in the Elderly Population

The greatest impact of arthritis is morbidity and disability, with the major burden being on the elderly population. Arthritis is the most frequently cited cause of activity limitations for men and women over age 45, compared to other chronic conditions, with the prevalence of arthritis disability being generally higher in females. According to data from the US National Longitudinal Study on Aging of 1984, community-dwelling elderly (ages 70+) who report arthritis represent the greatest proportion of individuals with physical limitations (68%), limitations in activities of daily living (ADLs) (75%), and limitations in instrumental ADLs (70%) such as shopping, managing money, and housework. Epidemiologic studies at long-term care facilities in the United States have shown that 45–80% of residents have substantial pain from musculoskeletal origin that affects their functional status and quality of life.

RA and other inflammatory arthropathies are commonly viewed as the most likely types of arthritis to lead to disability. Data from population surveys suggest, however, that the most frequent cause of arthritis-related disability is OA. Although a smaller proportion of people with OA than with RA experience disability, because of its much higher overall prevalence, OA is the most frequent cause of disabling arthritis. Population data suggest that for every person with severe disability from RA, there are over seven individuals with severe disability due to OA.

Disabling arthritis is likely to have an impact on all aspects of life. **Table 3** presents a picture of the scope of impact on individuals age 65 or older with arthritis-related disability. The data are from the 1986 Canadian Health and Activity Limitation Survey (HALS). Results from the most recent version of this survey indicate similar findings, but at the time of writing, detailed data were unavailable. Although the data cannot be broken down into types of arthritis, it is important to remember that the majority of people with disabling arthritis in this age group will have OA, which is predominant in the aging population.

For people with arthritis-associated disability, there may be an impact on many aspects of life. Mobility, including walking, standing, and climbing stairs, may be impaired, leading to loss of physical independence, with the need to rely on walking aids and the help of other people. There is also an effect on occupation, including work, leisure, and obligations in the home. This may lead to loss of economic self-sufficiency, not only through reduced earning power, but also as a result of extra expenses incurred because of the disease. Furthermore, social integration may be affected along with relationships with other people. The combination of these factors may eventually contribute to depression and poor psychosocial function.

Management of Arthritis Impact

The principles for management of the painful and disabling consequences of arthritis are similar for all types of arthritis. Ideally, arthritis is treated early to halt its progression and prevent impairment and disability. The medical management of specific types of arthritis was previously discussed. More generally, a family physician or general practitioner (or in some cases a nurse practitioner or rehabilitation specialist) may manage the arthritis problem if it is

Table 3 Indicators of the effect of arthritis on the lives of those with arthritis-associated disability over the age of 65 in Canada

Indicator of effect on daily life	*Persons with disability affected over the age of 65 (%)*
Mobility	
At least some trouble with mobility[a]	92.5
Trouble or unable to climb stairs	69.2
Trouble or unable to walk 400 yards	70.5
Trouble or unable to stand >20 min	68.0
Cannot leave residence or only with attendant	33.8
Physical independence	
Some dependence because of disability[b]	74.1
Dependent on help weekly or more often[b]	51.5
Trouble or unable to bend to pick up object	52.3
Trouble or unable to cut toe nails or fingernails	48.6
Trouble or unable to get in or out of bed	20.1
Trouble or unable to dress	17.2
Social integration	
Lives alone	32.8
Never visits relatives or friends	19.8
Occupation	
Never attends sporting events, concerts, plays, or movies	83.3
Never participates in hobbies, arts, crafts	46.0
Never participates in social activities	20.1
Socioeconomic self-sufficiency	
Income <$20 000	63.4
Out-of-pocket expenses because of disability[c]	35.6
Base population >age 65 (thousands)	266 195

[a]Has trouble with or is unable to do one or more of the following: walk 400 yards without resting, walk up or down a flight of stairs, carry an object of 10 lbs for 30 ft, move from one room to another, stand for more than 20 min.

[b]Dependence, help because of health problem. Occasional: heavy household chores; looking after personal finances (e.g., banking, paying bills). Weekly or more frequent: shopping for groceries or other necessities; everyday housework. Daily: personal care (e.g., washing, grooming, dressing, feeding); moving about within own residence; preparing meals.

[c]Out-of-pocket expenses for medication, special aids or supplies, health and medical services not covered by insurance, modifications to residence, transportation personal services (e.g., attendant, housekeeping services).

Data from the 1986 Canadian Health and Activity Limitation Survey.

straightforward or can act as a gatekeeper for referral to other services. Unfortunately, research shows that due to inadequate training regarding musculoskeletal conditions, primary care management may be suboptimal. The medical specialists specifically trained in the diagnosis and treatment of individuals with arthritis are rheumatologists, orthopedic surgeons, and rehabilitation medicine specialists. Medical care usually includes a complete diagnostic work-up, advice regarding the appropriate drug regime, and appropriate monitoring of the patient for medication side effects. Tertiary care services may also be provided in some centers by rheumatologists who specialize in some of the rarer arthritis disorders. Appropriate and timely referral to orthopedic surgery is also important, particularly in view of the potential for total joint replacements and other types of surgery to control pain and restore function.

Physical therapy and occupational therapy are also important in the management of arthritis. Physical therapy strategies aim to maintain or increase range of motion, correct or prevent muscle weakness or wasting (which may also lead to instability of joints), and help correct malalignment of joints, abnormal use of joints, or both. Hydrotherapy (exercise in water) can have advantages, particularly for people with severe arthritis, as the buoyancy of water helps reduce the stress on the joints. Exercise can reduce pain, suppress the need for medication, and help maintain function. There is also some suggestion that cartilage repair occurs with a regular program of exercise.

It is important to encourage moderate levels of general physical activity within the limits of severe fatigue. Brief periods of several days of enforced rest may be followed by loss of muscle strength, with the risk of permanent decline in functional ability, including ability to walk. Even in the presence of active RA with constitutional manifestations, it is important that elderly persons maintain a certain level of physical activity to maintain function.

Occupational therapists are involved in the care of people with arthritis, by constructing splints to stabilize joints and reduce pain, and by providing input regarding environmental modifications to facilitate the performance of ADLs. Occupational therapists also conduct functional evaluations that are essential for treatment planning for older patients. Being able to transfer from a chair to a standing position, walk short distances, and get on and off a toilet independently may make the difference between living independently and requiring physical assistance or even institutionalization. Occupational therapists also offer education regarding joint protection and energy conservation techniques, which may help to reduce and improve joint alignment and prevent muscle fatigue.

Both occupational therapists and physical therapists may provide input regarding assistive devices and environmental modifications. The availability and use of assistive devices can make an important contribution to maintaining independence in people with arthritis disability. Assistive devices may be useful, for example, to help put on shoes and stockings or to open jars. Other devices include raised

chair or toilet seats to facilitate rising from a sitting position, and bath seats to assist with bathing. Adapted shoes are also particularly important in lower limb arthritis. Extra-depth shoes and orthotics may accommodate the anatomical changes of aging and help cushion the heel to absorb impact loading. Simple walking aids such as a cane can also reduce joint loading and decrease pain. Finally, adaptations to the physical environment in the home, such as handrails in the bathroom and on stairs, may be important in preserving independence.

Education is another important management strategy that may be offered at many different levels. Physicians, therapists, and trained laypeople may all be involved in educating people about their arthritis. Education is important to promote the patient's and family's understanding of the condition, so they know what they can do to adapt and cope with pain and the disabilities that may result from arthritis. Educational and community support interventions have been found to have a positive impact on many aspects of health status, including knowledge, pain, compliance with medication, emotional and social well-being, and disability. Programs that include and emphasize problem solving, coping, self-efficacy, and endurance exercise have proven more effective than traditional programs that focus exclusively on changes in the joints, range of movement, and joint protection.

All of these management strategies focus on the individual and on what can be done within the immediate environment to manage arthritis. The broad social environment can also make an important contribution to reducing the impact of arthritis on individuals. The social environment encompasses the attitudes of others, both within the family and in the community in general, cultural background, values, and expectations. Increased public awareness of arthritis could result in changes that would greatly enhance an individual's quality of life, by providing a more accepting and adaptable environment that would ultimately facilitate function of older people with arthritis.

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See also: Disability, Functional Status and Activities of Daily Living; Mobility and Flexibility; Osteoporosis and Aging-Related Bone Disorders.

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Assessment: Neuropsychological

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Glossary

Clinical Neuropsychology – A subfield of clinical psychology involving systematic evaluation, rehabilitation, and treatment of cognitive and other neurobehavioral deficits, generally using standardized psychometrically validated neuropsychological tests, among people with known or possible neurologic or neuropsychiatric conditions.

Neuropsychology – The study of relationships between the central nervous system and the mind.

Introduction

Literally defined, the term neuropsychology refers to the study of relationships between the central

nervous system (CNS) and the mind (or *psyche*). In that sense of the word (although not necessarily under that name), neuropsychology has had an extraordinarily long history in psychology, medicine (including psychiatry and neurology), and philosophy. Moreover, neuropsychological inquiry remains a central part of a range of interrelated scientific disciplines, such as cognitive neuroscience, behavioral neurology, neuropsychiatry, experimental neuropsychology, and the like. In contemporary times, the term clinical neuropsychology has a more specific connotation, referring to a subfield of clinical psychology involving systematic evaluation, rehabilitation, and treatment of cognitive and other neurobehavioral deficits, generally using standardized psychometrically validated neuropsychological tests, among people with known or possible neurologic or neuropsychiatric conditions.

The focus of this article is the contemporary meaning of neuropsychology, with particular emphasis on the role and relevance of neurocognitive assessment in the clinical care of older patients. The intent is to provide a broad introductory overview for geriatric health-care professionals regarding the nature and role of clinical neuropsychological assessment. The specific goals are twofold: (1) to raise awareness among non-neuropsychologist clinicians regarding the potential value of referring geriatric patients for neuropsychological assessment, and (2) to provide a resource so that non-neuropsychologist clinicians can be educated consumers of neuropsychological referral resources and results.

Definitions and Process of Neuropsychological Assessment

Who or What Is a Neuropsychologist?

As noted previously, under the broader rubric of neuropsychology as the study of the relationship between the CNS and neurobehavioral functioning, the term neuropsychologist is not discipline specific. Professionals from a range of related disciplines, including cognitive neuroscience, behavioral neurology, biological psychiatry, biological and cognitive psychology, and experimental neuropsychology, conduct neuropsychology as a field of scientific inquiry. However, contemporary use of the label clinical neuropsychologist is generally taken to refer more specifically to a doctoral-level clinical psychologist, with specific training relevant to the application of neuropsychology in clinical work with patients, as well as in clinical research.

In addition to meeting all the training requirements for a doctorate, licensure, and credentialing as a clinical psychologist, those practicing clinical neuropsychology also need to obtain the relevant knowledge and experience specific to understanding and evaluating brain–behavioral relationships and working with brain-injured or other neurologic patients. All neuropsychologists should have particular expertise in neuropsychological assessment and interpretation, a detailed understanding of the various cognitive and behavioral profiles of patient populations, and specific supervised experience in the practice of clinical neuropsychology. Neuropsychologists also have working knowledge, and often particular expertise, in such subdisciplines as functional neuroanatomy, neurodevelopment, and neurologic disorders/neuropathology. These skills are generally obtained via both formal course work and supervised clinical work conducted during both doctoral training, and 1 or 2 years of supervised postdoctoral training. In the context of working with older patients, neuropsychologists are expected to also have a solid knowledge base and relevant experience in geriatric psychiatry and gerontology. In addition to licensure (required by every state for independent practice of clinical psychology), many clinical neuropsychologists also go on to seek and obtain board certification from the American Board of Clinical Neuropsychology, which is a part of the American Board of Professional Psychology, and/or from the American Board of Clinical Neuropsychology.

Neuropsychological Testing and Neuropsychological Assessment

A central component of a comprehensive neuropsychological evaluation generally includes administration and scoring of standardized tests to measure a range of relatively specific neurocognitive abilities, such as attention/working memory, verbal knowledge and receptive/expressive language functions, visuospatial and constructional skills, mental processing/psychomotor speed, executive functioning, and visual or auditory learning/memory.

Standardized testing implies that the test administration procedures, instructions to the examinee, stimuli, and scoring procedures have all been clearly specified and validated as part of the test development process. These standardized procedures allow neuropsychologists to establish reliability, such as internal consistency, interrater reliability, and test–retest reliability, where appropriate. Standardized testing also typically involves the use of normative data. Normative data are gathered from healthy controls, or sometimes from various clinical populations, using the standardized procedures. The use of normative data allows for evaluation of an examinee's performance

relative to that expected in the overall general or patient population, as well as among demographically similar healthy controls. For instance, in evaluating older patients, it is helpful to consider performance relative to age-matched peers, particularly on tests of abilities that are strongly affected by normal aging, such as psychomotor speed. This aids in distinguishing genuine but non-pathological difficulties, e.g., normal age-related forgetfulness, from those that are likely to reflect a pathological cause, e.g., a neurodegenerative condition.

There are at least two specific advantages of testing a range of cognitive abilities rather than simply examining overall cognitive functioning: (1) some disorders or localized brain lesions will impair certain abilities while leaving others relatively intact, so examination of the pattern of cognitive strengths and deficits can provide some clues regarding the nature of any present neuropathology, and (2) information about spared or residual abilities is at least as important as that regarding impaired abilities when developing plans for treatment or compensatory strategies.

Use of standardized neuropsychological tests is generally central to a neuropsychological evaluation, but the process of neuropsychological assessment is much broader and more complex than administering and scoring standardized tests. (Some neuropsychologists in fact delegate at least a portion of the actual test administration and scoring to a well-trained and supervised bachelor-level psychometrist/technician.) Rather, a neuropsychologist's training and expertise are most salient in the process of integrating and interpreting standardized test scores in the context of other available information, such as the presenting concerns, detailed behavioral observations, clinical interview of the patient and any available family members or caregivers, review of current and past psychosocial functioning, medical history, and personality functioning. The ability to form a coherent synthesis of this breadth of information, together with a consideration of the pattern of performance across a range of specific neuropsychological tests, is where both the science and art of a clinical neuropsychologist's knowledge, skill, and expertise become most apparent.

Origins and Current Roles of Neuropsychological Assessment

Detection and Localization of Neuropathology

Although neuropsychology has long historical roots, it only emerged as a subdiscipline within clinical psychology in the early- to mid-twentieth century. During the initial development period, the primary emphasis of clinical neuropsychology was detecting and/or localizing brain injury or other forms of CNS dysfunction, as well as characterizing the nature of brain injury. Indeed, many of the neuropsychological tests and techniques that are still in use today were originally designed or adapted for such purposes. For instance, in the 1930s, Ward Halstead, one of the pioneers of clinical neuropsychology, carefully observed people with brain injuries in an effort to understand the effects of such injuries on cognitive processes and behaviors. When he observed a potentially relevant behavior, he designed methods to measure or quantify that behavior. For example, having noted that many brain-injured patients had partial unilateral paralysis, Halstead developed the finger oscillation test, more commonly known as the finger tapping test, among other tests, to quantify motor difficulties. With this approach Halstead developed a battery of tests that was subsequently refined, expanded, and further validated by Ralph Reitan into what is now known as the Halstead–Reitan Battery. Portions of this battery remain among the most widely used neuropsychological tests.

Other commonly used measures of cognitive function include subtests from other batteries such as the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Memory Scale (WMS) in their various incarnations. Although earlier versions of WAIS and WMS were primarily used to measured intelligence and memory, respectively, the latest editions allow for the computation of index scores for specific neurocognitive ability areas, i.e., verbal comprehension, processing speed, perceptual organization, working memory, verbal memory, and visual memory, therefore rendering them appropriate neuropsychological instruments.

Over the last few decades, the use of neuropsychological assessment in lesion detection and localization has decreased with the development and increased availability of neuroimaging techniques such as computerized tomography (CT) and magnetic resonance imaging (MRI). But neuroimaging has not fully eliminated the usefulness of neuropsychological assessment in this regard. Neuropsychological tests are often sensitive to subtle forms of neuropathology that are not readily discernible through contemporary imaging methods. For instance, because some cell and brain volume loss, as well as plaques and tangles, are common in normal aging, the neuropathologic changes in the early stages of Alzheimer's disease (AD) can be quite difficult to distinguish from those associated with normal aging via imaging alone; however, the subtle deficits in episodic verbal memory (beyond those

attributable to normal aging) may be detected through neuropsychological evaluation. Similarly, functionally relevant non-focal lesions from traumatic head injury or other forms of neuropathology may affect neuropsychological performance and everyday functioning without clearly discernible abnormalities seen via CT or MRI.

Differential Diagnosis

Neuropsychological assessment is also frequently useful in the process of differential diagnosis of suspected neurocognitive disorders. A key component of differential diagnosis is the ability to measure relatively discrete cognitive functions, disentangle these cognitive abilities, and compare the level of observed performance to normative data from similarly aged individuals in the general population. A practical and common example is when a neuropsychologist is asked to evaluate an older adult's complaint of increasing forgetfulness. Many times what is perceived by a layperson as a memory deficit may, through neuropsychological evaluation, be revealed to be attributable to some other type of deficit, such as sensory-perceptual problems, attentional difficulties, and organizational or other executive dysfunctions, and/or may reflect depression or anxiety, or both. Skilled neuropsychologists are able to distinguish between these various potential etiologies of increasing forgetfulness and make recommendations and develop treatment plans that are targeted to the specific cause of these complaints.

Determining and Quantifying the Cognitive/Functional Impact of Known Neuropathology

Another key role of neuropsychological assessment is evaluating the cognitive and functional effects of known neurologic injuries or lesions. For instance, it may already be known that a particular patient has early AD, or has experienced a stroke or head injury affecting a specific brain region, but the effects of the known neuropathology on specific cognitive abilities and everyday functioning may remain unclear without thorough neuropsychological evaluation. In fact, over the last decade or so, there has been a growing emphasis in clinical neuropsychology in not simply documenting the presence of cognitive deficits, but also discerning the implications for such deficits in terms of everyday functioning. For example, neuroimaging may be able to identify that a patient has a lesion to the hippocampus, a structure known to be important in the formation of new memories; however, such images often tell clinicians little about the extent of the memory impairment and what this impairment means for the patient's everyday functioning. Therefore, neuropsychology can also be extremely important in the rehabilitative process and may complement such disciplines as occupational and physical therapy. For instance, even if a patient's cognitive deficits are not expected to substantially recover, clarification of his or her specific strengths and weaknesses can be key in developing compensatory strategies (whether these involve teaching the individual to rely more heavily on spared abilities or making environmental modifications to decrease the potential influence of salient deficits).

Evaluating Current and Future Decline or Recovery

Yet another common role of neuropsychological assessment in geriatric mental health and other clinical settings is determining the speed and trajectory of cognitive changes, either in terms of the rate of decline, e.g., from a neurodegenerative condition such as AD, or in terms of the rate and level of recovery, e.g., from stroke or traumatic head injury. In this vein, repeated neuropsychological assessment can be an invaluable component in long-term treatment and care planning. Some common difficulties associated with interpreting changes over repeated assessments are that examinees' performance may improve due to their becomig more familiar with the content and/or test methods, and there are generally some mild fluctuations in test scores over successive evaluations simply due to random effects. Thus, a particularly interesting and useful development in clinical neuropsychology over the past decade has been the increased interest and preliminary work among neuropsychologists to develop norms for change by which observed changes can be evaluated relative to the degree of expected practice effects and random fluctuations.

Role of Neuropsychology in the Diagnosis and Treatment of Patients with Non-Neurologic Disorders

In many clinical settings, there may be a tendency to think of neuropsychological assessment primarily in terms of working with patients with acquired neurologic conditions, such as head injury, stroke, brain tumor, and/or progressive neurodegenerative conditions. Indeed, neuropsychologists are important and valuable in the evaluation and treatment of such patients. However, other disorders frequently seen in geriatric and other mental health settings, such as mood disorders and psychosis, also commonly have clear and functionally relevant neurocognitive aspects. Even many non-neuropsychiatric medical conditions, such as cancer, cardiovascular disorders, liver disease, endocrine disorders, and some forms of

infectious disease, particularly HIV infection, and/or their treatment may adversely affect cognitive abilities to a functionally relevant degree. In terms of primary psychiatric disorders, there is a large literature on the predictors of everyday functioning and outcome among older as well as younger patients, which clearly demonstrates that neuropsychological skills, but neither primary psychiatric symptoms nor demographic characteristics, such as age or education, are the strongest predictors of level of independent functioning and long-term outcome. In short, neurocognitive assessment, whether brief screening or comprehensive assessment, has clear relevance and utility in the evaluation, treatment, and care planning for geriatric patients with neurologic, psychiatric, and other medical conditions.

Assessment of Specific Neuropsychological Domains

As described previously, a central foundation of neuropsychological assessment is the view that cognitive functioning can be, to some degree, described in terms of a number of more specific abilities that reflect the functioning of relatively discrete brain regions or systems. A thorough description of these constructs and the variety of tests available to measure each of the constructs and subconstructs is beyond the scope of the present article. Nevertheless, the following brief examples are provided to give those unfamiliar with the details of neuropsychological assessment a tangible understanding of the manner in which these constructs tend to be operationalized.

Attention and Working Memory

The term attention is a rather broad construct that refers to a range of more specific abilities, such as simple or basic attention (such as the ability to repeat back strings of digits), selective or focused attention (distinguishing relevant from irrelevant stimuli or information), maintenance over time (ability to stay mentally on track), and vigilance (such as waiting for a particular stimulus or event over time). The concept of working memory is closely related to attention, but also to that of executive functioning, described later. Working memory is generally conceptualized as the short-term 'mental work bench,' where information is actively held for short periods of time for further processing. A key aspect of working memory is that it has limited capacity and requires active rehearsal or allocation of attentional resources for retention. For instance, if an individual needs to hold a telephone number in his or her working memory for a period sufficient to dial the telephone, that retention is generally facilitated by active rehearsal over the delay period. Given the diffuse nature of attention as a neuropsychological construct, there is not one neuroanatomical region responsible for these abilities; however, it is widely accepted that relatively intact frontal lobes are needed for most attentional skills.

Some common examples of attention and/or working memory tasks include the serial 7s subtraction subtask from the Mini-Mental State Examination (MMSE) and the Digit Span subtest from third editions of the WAIS (WAIS-III) and WMS (WMS-III). In the latter, the examinee is first asked to repeat strings of digits of increasing length and then in the second half is asked to repeat strings of digits in reverse order. Others include any of the various cancellation tasks; examples include the Digit Vigilance from the expanded Halstead–Reitan Battery, in which the examinee is asked to rapidly identify and cross out every instance of a target number within a much larger array of numbers, and any of the various versions of the Continuous Performance Test (CPT), such as the identical pairs version, in which the examinee watches a series of numbers rapidly flashed on a computer screen and is required to make a response after any number is shown twice in a row. There are also spatial working memory tasks, e.g., in which examinees are asked to remember the location of a particular stimulus over a brief delay and/or to tap out a sequence of blocks in the same or reverse order as presented by the examiner, e.g., the Spatial Span subtest of the WMS-III.

Verbal Abilities

Verbal abilities may include both crystallized knowledge and language functions. Crystallized knowledge is declarative knowledge of the type that is generally acquired in school or other social or learning environments and experiences. Examples of tests used to measure this construct include vocabulary knowledge as measured by the WAIS-III Vocabulary subtest, in which the examinee is asked to define a series of presented words, and general information as evaluated by the WAIS-III Information subtest, in which the examinee is asked to answer common knowledge questions.

Common receptive language measures may include both written presentation, as in reading comprehension tasks, and tasks such as the Token Test, in which the examinee is required to follow a succession of increasingly complex aurally presented instructions, and the Complex Ideational subtest from the Boston Diagnostic Aphasia Examination, which

requires the examinee to answer several two-part aurally presented questions. Two examples of commonly used expressive language tests include the Boston Naming Test, in which the examinee is shown drawings of objects one at a time and asked to identify each one in succession, and letter fluency tasks, such as the FAS task, in which the examinee is given three 1-min trials to name as many words as he or she can think of that begin with the letters F, A, and S, respectively. Lesions to brain areas known to mediate specific language skills, such as Broca's area of the frontal lobe, which is important in the motor programming of speech, and Wernicke's area of the temporal lobe, which is involved in the auditory comprehension of spoken words, would impact performance on some of these tasks.

Visual-Spatial and Constructional Skills

Visual-spatial or perceptual organizational skills refer not simply to visual acuity, but moreover to the ability to discern the pattern and relative location of visual stimuli, as well as manipulate objects in three-dimensional space. Common measures of these abilities include several subtests from the WAIS-III, e.g., Block Design, in which the examinee is required to rapidly match a two-dimensional figure by combining three-dimensional colored blocks, Picture Completion, in which the examinee must identify the important missing element in a series of pictured scenes, and Matrix Reasoning, a visual reasoning task in which the examinee must identify the missing element in a matrix by discerning the rule underlying the relationship between each of several subparts. Another widely used test in this area is the Hooper Visual Organization Test, in which the examinee is shown several pictured objects that have been cut and randomly arranged in pieces; the examinee must mentally rotate the various pieces and put them together, and then name the object. Posterior right hemisphere lesions are often responsible for impairment on many visuospatial and construction tasks; however, left hemisphere lesions can also disrupt these abilities, but typically present with a different pattern of impairment.

Mental Processing and Psychomotor Speed

Psychomotor and mental processing speed refer to the speed of thinking and/or integration of speed of thinking with rapid motor action. Common measures of this domain include the WAIS-III Digit Symbol task, in which the examinee is asked to rapidly draw a set of symbols that are matched via a key to a series of numbers, and the Trail Making Test (Part A). The latter task was originally developed in the 1930s by John Partington and published as Partington's Pathways Test; it requires the examinee to rapidly connect a series of circled numbers. At least one test of psychomotor speed is almost invariably included in neuropsychological evaluations, as these tests tend to be among the most sensitive to any form of CNS dysfunction. However, this is also the domain most clearly and consistently affected by normal aging. Declines in psychomotor speed relative to younger adults are evident among those in their 30s, and slowing progresses with further aging.

Neuropsychological batteries also commonly include more direct measures of motor functioning, e.g., the Hand Dynamometer Test of grip strength, in which the examinee's strength in each hand is evaluated, and Test of fine motor dexterity the Grooved Pegboard in which the examinee is required to rapidly place a series of keyed pegs into metal slots. These motor tasks can be particularly helpful in identifying lateralized patterns of impairment, and specifically lesion to the motor cortex, as well as having potential implications for everyday functioning.

Executive Functioning

The term executive functions is one that is particularly important in describing human cognition, yet at the same time it is one of the most difficult to precisely define. Very broadly, executive functions are those higher-order functions that allow an individual to initiate and maintain goal-directed behavior, as well as to disengage from such behaviors when appropriate to the goals and/or in response to environmental cues. Some of the underlying skills generally classified within this area include abstraction and problem solving, cognitive flexibility and set shifting, response inhibition, and planning. As noted previously, the concept of working memory also has some overlap with that of executive functioning. Historically, the term executive functions was frequently used interchangeably with the term frontal-lobe functions (with particular emphasis on the prefrontal cortical regions). However, not all activities of the frontal lobe are executive in nature, and the neurologic systems needed to carry out these executive functions are clearly not limited to the frontal lobe; over the past two decades, there has been increased recognition of the role of frontal–subcortical circuits in the various executive functions.

Some of the most widely used measures of executive functions include the Wisconsin Card Sorting Test (WCST), Booklet Category Test, Stroop task, and Trail Making Test (Part B). Consideration of the specific tasks in each of these tests is helpful in

illustrating the range of functions subsumed under the label of executive skills. For instance, successful performance of the WCST requires the examinee to discern an unspoken rule that defines correct versus incorrect matches, and also requires the examinee to change strategies when appropriate. The Booklet Category Test similarly requires the examinee to discern the pattern or rule underlying the sequence of presented stimuli, but that rule may change over various subsections. Thus, the WCST and Booklet Category Test may both measure abstraction/problem solving, as well as mental flexibility (or perseverative thinking). The Stroop task seems to require a somewhat different skill, particularly response inhibition. On the color–word interference portion of this task, the examinee must rapidly tell the examiner the color of the ink that the word is printed in rather than read the printed word (e.g., say the word red when the word blue is printed in red ink). This requires the examinee to inhibit the more automatic or quickly processed reading response in favor of a more effortful color-naming response. Trail Making Test Part B is generally administered immediately after Part A (described previously), and requires the examinee to rapidly connect a series of numbers and letters (alternating between the number and letter sequences). Letter fluency (FAS, described earlier) as well as category fluency, such as the ability to rapidly name types of animals, are also sometimes interpreted in terms of executive functions, as rapid performance is facilitated by use of an effective strategy for mental search of the lexicon.

Learning and Memory

Neuropsychological batteries, particularly those used with older patients, almost invariably include one or more measures of auditory and visual episodic declarative memory. Tests of auditory and visual episodic learning and memory have similar methods; they often include several trials, followed by a delay trial. Distraction tasks or other neuropsychological tests are often administered during the delay period to prevent rehearsal of the test stimuli. Measures of delayed recall often include a free recall trial and recognition, and sometimes include cued recall. Examples of reliable and often-used measures of auditory learning and memory tests include the Hopkins Verbal Learning Test, Rey Auditory Verbal Learning Test, and California Verbal Learning Test, all of which are list-learning tasks, and Logical Memory (from the WMS-III), in which the stimuli are stories or short passages. Visual learning is often measured with the Brief Visuospatial Memory Test (BVMT) and the WMS-III Visual Reproductions (VR) and Family Pictures subtests. One thing to note about the BVMT and VR is that both not only require the examinee to learn and remember geometric figures, but the free recall portions also require the examinee to draw those figures. Thus, each of these latter tests also has a visual-constructional element in addition to a visual memory component. This provides yet another example of why neuropsychologists are reluctant to interpret isolated test scores: performance on one test may color the appropriate interpretation of a second test. Encoding and retrieval of new information are thought to be dependent on the intact functioning of the hippocampus and associated parahippocampal gyri, although recent literature has shown that the frontal lobes are also involved in these abilities. And, as was pointed out previously, many of these tests require additional cognitive skills (such as visual-constructional skills) that are not controlled by these neuroanatomical areas.

Other Assessments

In addition to tests of the preceding or similar constructs, comprehensive neuropsychological assessment frequently includes measures to estimate premorbid functioning, as well as standardized measures of motivation or effort. In terms of premorbid functioning, word reading (another example of crystallized knowledge) tends to be relatively resilient to the effect of many (although not all) forms of acquired neurologic dysfunction. Thus, word reading measures such as the American National Adult Reading Test or the Word Reading subtest from the Wide Range Achievement Test, third edition, are often included as part of an overall neuropsychological evaluation as a way of estimating premorbid verbal functioning.

Tests of motivation and effort (or symptom validity testing) are most frequently employed in forensic contexts, in which there may be some monetary or other tangible benefits to the examinee to appear cognitively impaired. These tests can also be useful in other contexts to detect suboptimal effort. (These symptom validity tests are sometimes loosely referred to as malingering tests, although, strictly speaking, this term is generally inappropriate in that it implies consciously motivated deficient performance. It is generally difficult to prove that suboptimal performance is consciously motivated.)

Effects of Normal Aging on Neuropsychological Functioning

Normal aging can affect the various cognitive abilities to different degrees. Perhaps the single most

consistent finding is that of slowed psychomotor speed with age; in fact, some researchers have suggested that other normal aging-related cognitive changes are in fact due to the effects of this psychomotor slowing. Psychomotor slowing is not limited to the elderly, but rather progresses throughout most of the adult life span. People in their 30s, on average, have slower performance on psychomotor tasks than those in their 20s; the average performance of people in their late 80s on the WAIS-III Digit Symbol subtest is two standard deviations below the mean of that of people in their 20s.

In addition to slower processing speed, one of the most frequent and salient changes with normal aging, particularly among the elderly, is a modest decline in efficiency of information acquisition and free recall retrieval (as evidenced on auditory or visual measures of episodic declarative memory). In contrast, however, actual retention of information, as evaluated through cued recall and/or recognition test formats, tends to be less affected by normal aging than initial acquisition and free recall. This contrast can be important in distinguishing normal forgetfulness from a pathological process. For instance, the hallmark of AD is a progressive decline in both efficiency of acquisition and retention of acquired information. In fact, some evidence suggests that greater than age-normal declines in episodic declarative memory may serve as an early marker of the preclinical stages of AD.

Normal aging can also be associated with some declines in perceptual-organizational/constructional skills, as well as executive functions, and some aspects of working memory, particularly those requiring more active manipulation of information, rather than simple momentary rehearsal and storage. In contrast, performance on verbal tasks (other than verbal memory) tends to be relatively unaffected, particularly those emphasizing crystallized verbal knowledge. For example, comparison of the various age group norms for the WAIS-III Vocabulary test suggests that vocabulary knowledge remains stable or even increases through the late 70s, and even among those in their 80s, declines are relatively modest. Thus, an apparent change in an older person's crystallized knowledge, particularly if that knowledge cannot be elicited even through recognition, warrants further inquiry for possible pathological processes.

In addition to savings (retention), recognition, and verbal knowledge, basic attention also tends to be relatively unaffected by normal aging. For instance, age accounts for only about 2% of variance in the performance of Digit Span scores within the general population, although the backward component can be more difficult, as it draws more heavily on the executive functioning aspects of working memory. Aging also appears to have minimal influence on vigilance, such as measured by errors of omission on CPT tasks, although there is some evidence that commission errors may increase, perhaps reflecting more difficulty with response inhibition. Among attentional tasks, age appears to have a stronger effect on cancellation tasks such as the Digit Vigilance task. This may in part be secondary to changes in processing speed, as most cancellation tasks require rapid performance. (This possibility also illustrates the dangers of interpreting scores from an individual test in isolation, e.g., impaired versus intact performance on measures of psychomotor/processing speed would appropriately affect interpretation of impaired scores on a cancellation task purely in terms of attentional difficulties.)

Screening versus Comprehensive Assessment

One common concern that arises in applied settings is that a comprehensive neuropsychological evaluation may require several hours to complete. Indeed, due to changes in managed care and health-care reimbursement patterns, many clinical neuropsychologists are under increasing pressure to streamline cognitive assessments. There are many contexts in which full and comprehensive neuropsychological evaluation is clearly warranted, and the time is easily justified. For other situations, such as general or routine screening, however, there also exist shorter screening methods.

The Folstein Mini Mental State Examination (MMSE) is probably the most widely used cognitive measure in medical and psychiatric settings. The MMSE is a 30-item measure that includes items related to orientation, attention/working memory, recall, language and constructional skill. Advantages of the MMSE include ease and time of administration (it can be administered by trained staff, and it generally requires 10 minutes or less), and because it is so widely used, most clinicians have a general sense of what to expect from patients with MMSE scores in various ranges. It also can be frequently repeated to document the course of cognitive decline. Due to these aspects, the MMSE is a useful (if imperfect) tool to include in general clinical evaluation, particularly with older adults. It must be noted, however, that the MMSE items are quite easy for cognitively intact or even mildly impaired individuals, and it is strongly influenced by education. Thus, a key disadvantage is that it is often insensitive (having a high

false-negative rate) as a general cognitive screening tool. Even people with AD sometimes score in the normal range of the MMSE, particularly those with high levels of education in the earlier stages of the disorder. Moreover, the MMSE tends to be even less sensitive to some other forms of neurocognitive deficits, such as subcortical dementias, e.g., dementia due to Parkinson's disease, or Huntington's disease. Finally, the MMSE fails to assess the domain of executive functioning, which may be among the most important in terms of ability to function independently, and is commonly affected by a number of neurocognitive disorders.

An intermediate choice between a very brief screening tool such as MMSE and a full comprehensive neuropsychological evaluation is a somewhat more comprehensive and sensitive screening battery. For instance, the Repeatable Battery for Assessment of Neuropsychological Status (RBANS) requires about 30 minutes to administer and screens for deficits in a number of cognitive functions of frequent interest. Another widely used option is to administer a subset of standard neuropsychological tests, either several tests from a cognitive domain of particular relevance to the presenting concern or one brief test from every major cognitive domain. More recently, computerized cognitive screening tests such as the MicroCog have been developed; they reduce time and administration burden. In any of these cases, there is clearly a tradeoff between savings in administration time versus depth and breadth of assessment. Nonetheless, these options are important to keep in mind, as wider or more routine incorporation of neuropsychological screening into standard clinical practice can be very useful when working with older patients, yet may often be avoided by some clinicians due to concerns about lengthy testing. By integrating a clinical neuropsychologist into the treatment team, and/or with clear communication between the referring clinician and the neuropsychologist, an effective and appropriate balance can generally be found to meet the needs and limitations of any particular clinical context.

Expanding Role of Neuropsychology in Treatment

Information garnered from such neuropsychological assessment can be an extremely valuable component of treatment in and out of geriatric health-care settings, including in those with neurologic, psychiatric, and general medical conditions that may affect cognition directly or through the effects of the primary treatment. Sometimes simply documenting the nature of specific cognitive deficits can be a substantial relief to patients and/or their family members. For example, some of the disinhibition that may be associated with executive dysfunctions can be particularly distressing to a patient's family members. Identification and explanation of the nature of executive dysfunction can be therapeutic for the family, as the behaviors are then recognized as unintentional. Identification of cognitive deficits and strengths (or at least relative sparing) is key to designing effective rehabilitation strategies, including teaching patients to rely on their strengths, as well as to planning environmental changes to diminish the potential influence of cognitive deficits.

Beyond compensatory strategies, direct treatment of cognitive deficits is itself an area of growing interest. For instance, cholinesterase inhibitors are now considered standard care for people with AD. Whereas presently available compounds convey at best modest and temporary benefits, there are research efforts underway to develop more efficacious treatments. As such treatments emerge for AD and other disorders, repeated cognitive evaluation will be key to documenting reversal (or at least delay of the progression) of cognitive decline. Likewise, there are emerging government, academic, and industry collaborative efforts, such as the MATRICS (Measurement and Treatment Research to Improve Cognition in Schizophrenia) and the TURNS (Treatment Units for Neurocognition in Schizophrenia) projects to foster development and evaluation of cognitive enhancing medications for the neurocognitive deficits associated with schizophrenia. As was noted previously, cognitive deficits have the most direct influence on level of everyday functioning and outcome; thus, as pharmacologic and other interventions for targeting cognitive deficits in a range of conditions begin to emerge, the importance of neuropsychological assessment will continue to expand as a means of gauging treatment needs and treatment effectiveness.

Summary and Conclusions

This article only briefly discusses the current and potential relevance of a neuropsychological perspective in the care of geriatric patients. Nonetheless, several key points are: (1) clinical neuropsychology is a unique discipline combining expertise from an array of disciplines relevant to systematic evaluation of brain–behavior relationships and patterns of specific neurocognitive strengths and weaknesses, and involves more than administration of standardized cognitive tests; (2) such evaluation can provide valuable information in detecting functionally relevant

cognitive deficits, differential diagnosis, determining the impact of known neurologic insults, and determining the speed and trajectory of cognitive decline or recovery, as well as in differentiating pathological changes from those associated with normal aging; (3) neuropsychological assessment has clear utility in the care and treatment of not only neurologic patients, but also those with psychiatric disorders and many other medical conditions; (4) there are numerous neuropsychological domains, and specific tests have been developed to assess these domains; (5) some age-related neuropsychological changes, such as declines in processing speed, are expected, whereas other cognitive abilities, such as crystallized verbal skills, should remain relatively intact over the life span; (6) comprehensive neuropsychological evaluations assess a wide variety of specific cognitive abilities, but a balance must be struck between comprehensive assessment and the need for time-efficient screening methods; and (7) neuropsychological evaluations are likely to continue to be important as newer treatments are developed for cognitive difficulties of various conditions. In short, clinical neuropsychological consultation can provide unique and valuable information to clinicians working with older patients.

See also: Brain and Central Nervous System; Information Processing/Cognition; Memory; Neuroimaging (MRI, PET).

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Atherosclerosis

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Glossary

Advanced Glycation End Products (AGEs) – Modified proteins or lipids, late products of nonenzymatic glycation and oxidation reactions.

Atherosclerosis – An inflammatory fibroproliferative disease of large arteries, of humans and most other species, that underlies almost all human coronary heart diseases, as well as many other cardiovascular diseases.

Chemokines – A subfamily of small cytokines (8–10 kDa), mostly known for their chemotactic properties, but recently shown to be involved in the control of cell proliferation, survival, and differentiation.

Cytokines – A family of secreted molecules with a role in many biological processes, such as cell activation, growth and differentiation, inflammation, and immunity.

Fibrous Cap Atheroma – An advanced stage of progressive atherosclerotic lesions characterized by a well-formed necrotic core with an overlying fibrous cap.

Hyperlipidemia – Elevated triglyceride or low-density lipoprotein (LDL) cholesterol levels and multiple lipoprotein metabolic abnormalities.

Inflammation – A series of responses of vascularized tissues to injury, i.e., stimuli or insults. It includes alteration of hemodynamic and vascular permeability and consequent infiltration of leukocytes. Inflammatory factors have recently been shown to

be produced by vascular cells and regulate their functions predisposing the vessel wall to an enhanced response to injury.

Intimal Xanthoma (Fatty Streak) – Accumulation of macrophages and lymphocytes within the thickened intima, without a necrotic core or fibrous cap.

Tunica Intima – A layer of endothelial cells lining the vessel lumen, in direct contact with the blood flow, separated from the tunica media by the internal elastic lamina.

Tunica Media – Middle layer of the vessel wall containing mostly smooth muscle cells interspessed with elastic lamallae.

Introduction

The average age of the population of Western countries is increasing. Demographic data show that in the United States, for example, 35 million people are now 65 years of age and older, and this number will double in 2030 (**Figure 1**). Although data from epidemiological studies have discovered that lipid levels, diabetes, sedentary lifestyle, and genetics are risk factors for cardiovascular diseases (CVDs) such as atherosclerosis, hypertension, congestive heart failure, and stroke, advancing age confers the major risk.

This article first describes the development of the atherosclerotic lesion in the context of the emerging role of inflammation, then reviews some of the epidemiological data that support the notion that aging is the major risk factor for atherosclerosis. Finally, it summarizes the age-associated changes within the vessel wall in humans and experimental animal models and discusses how specific pathophysiological mechanisms become superimposed on vascular substrates that have been modified by aging, therefore conferring upon age, per se, the role of the major risk factor for CVDs.

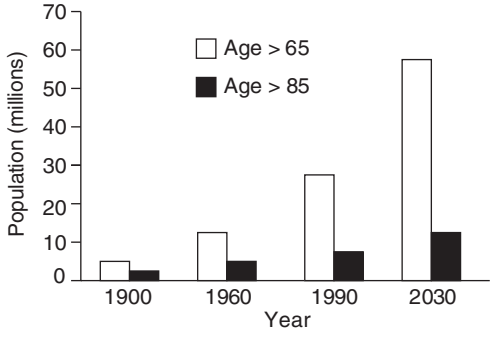

Figure 1 The demographic imperative of aging. Population of United States from 1900 to 2030. The white bars represent people 65 years of age and older; the black bars represent individuals 85 years and older. Data replotted from the US Census Bureau data, with projections for 2030. Reproduced with permission from Spinetti G. et al. 2004 Rat aortic MCP-1 and its receptor CCR2 increase with age and alter vascular smooth muscle cell function. Arteriosclerosis, Thrombosis, and Vascular Biology 24: 1397–1402, Lippincott Williams & Wilkins.

Pathogenesis of Atherosclerosis

Development of Atherosclerosis and Progression to Thrombosis and Clinical Events

Cardiovascular diseases are the leading cause of mortality in Western societies. Among these, atherosclerosis, a progressive disease in which lipids and extracellular matrix components accumulate in the large arteries, represents one of the most important contributors. The traditional view of the atherosclerotic lesion as a pool of lipid debris embedded in vascular smooth muscle cells (VSMCs) has dramatically changed in the past decade with the recognition of a prominent role for inflammation. This article reviews the characteristics of atherosclerotic plaque development and describes some new concepts associated with inflammatory cells and molecules.

Recently, experts in the field have revised the classification scheme of the American Heart Association (AHA) for atherosclerotic lesions. This new classification scheme is consistent with the AHA categories but does not imply an orderly, linear pattern in the progression of the lesion, as was the case of the former categories, and thus reflects the wide array of morphological modifications that are evident from recent autopsy studies. This article uses this morphological classification scheme.

The wall of large arteries is composed of three layers: the tunica intima, tunica media, and adventitia (**Figure 2**). The circulating blood is in direct contact with a monolayer of endothelial cells (ECs) that constitute the first barrier of the intima. In humans in addition to ECs, the intima contains few VSMCs, which are normally absent in most other species, and extracellular matrix components. In contrast, the medial layer is composed of VSMCs and matrix, which is represented by elastin and collagen. Two types of nonatherosclerotic arterial remodeling that can lead to atherosclerotic lesions are diffuse intimal thickening and intimal xanthoma (traditionally referred to as the fatty streak), although both conditions can exist without progression. Intimal thickening is characterized by VSMC accumulation in a proteoglycan-rich matrix, in the absence of leukocyte transmigration and lipids. In humans there are very few reports on the progression of localized intimal thickening to atherosclerotic

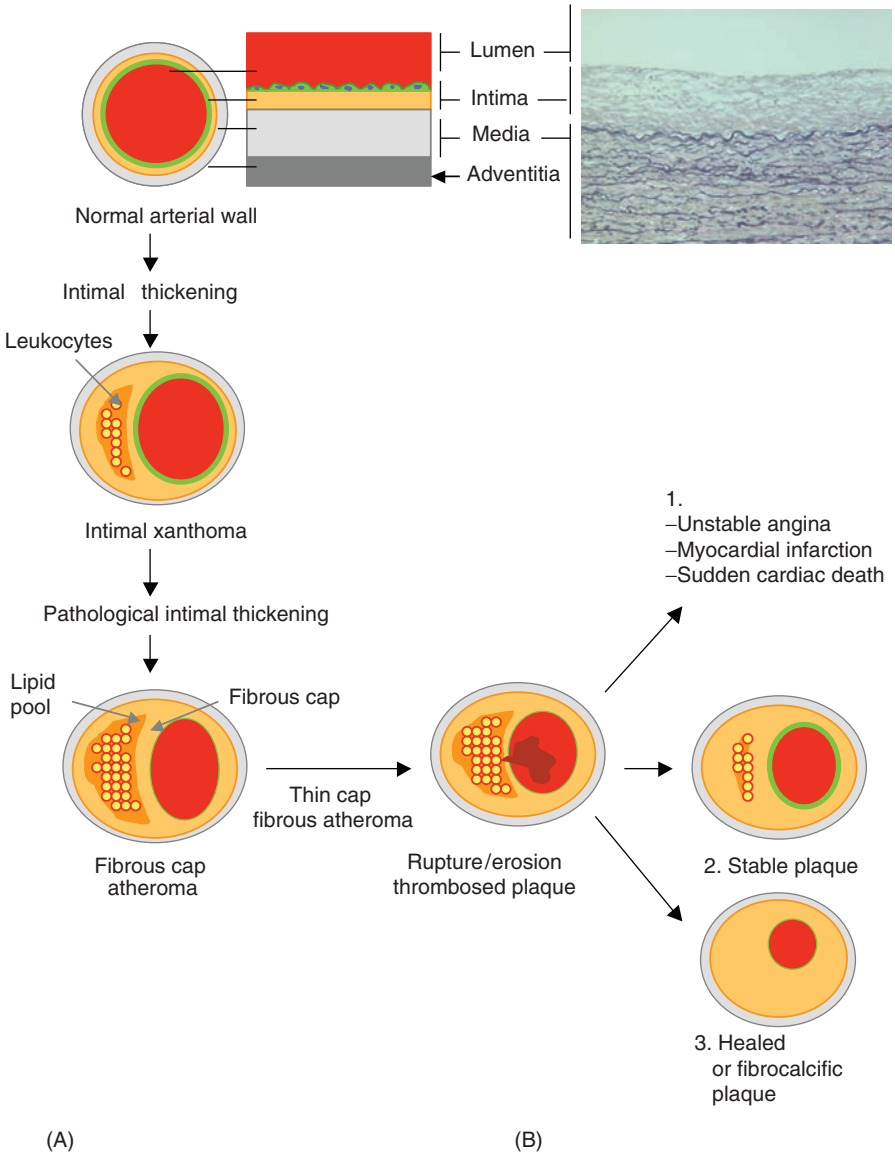

Figure 2 Schematic view of the development of an atherosclerotic lesion. (A) From the top to the bottom of the figure: the typical structure of the arterial wall to the atherosclerotic plaque and its healing or complications. Details are described in the text. The yellow circles represent leukocytes. (B) Photomicrographs of grossly normal human aorta. Original magnification: 100×. Note that the adventitia layer depicted in blue in the schematic view is not shown in the photomicrograph reported in panel B.

lesions. It is of note that, as reported by Velican, the distribution of this normal, developmental localized intimal thickening in children can be correlated with the distribution of characteristic lesions seen in adult humans. Moreover, a study from Kim et al. in swine shows that atherosclerotic lesions produced in the coronary by 90 days of feeding a hyperlipidemic (HL) diet arise almost exclusively in the normally occurring localized intimal thickening.

Intimal xanthomas are pre-atherosclerotic lesions in which macrophages and lymphocytes accumulate within the thickened intima without a necrotic core or fibrous cap. The human xanthomas, in most cases, can regress. In this respect, as shown by the aforementioned study by Velican et al. and by the results of the Pathobiological Determinants of Atherosclerosis in Youth (PDAY) study, the distribution of atherosclerotic lesions in the third decade of life and beyond is very different from the intimal xanthomas seen in children. Intimal thickening and xanthomas are present in all human populations, but xanthomas have been preferentially observed in association with exposure to the Western diet. Several observations show that this arterial remodeling is mediated by EC activation in response to risk factors such as hyperlipidemia. The activated ECs mediate the

recruitment of leukocytes by expressing adhesion molecules, i.e., vascular cell adhesion molecule (VCAM-1), P-selectins, E-selectins, and chemotactic molecules, mostly belonging to the chemokine subfamily of cytokines, that facilitate the rolling, adhesion, and consequent transmigration of leukocytes. Modified lipoproteins, i.e., oxidized phospholipids and aldehydes, or cytokines, i.e., interleukin (IL)-1β and tumor necrosis factor-α (TNF-α), can induce the nuclear factor-κB (NF-κB)-mediated increase in VCAM-1.

Shear stress can modulate atherosclerosis formation. Laminar shear stress (>15 dynes/cm^2 s^{-1}) is known to have a protective role, while turbulent, low shear stress (<5 dynes/cm^2 s) in regions of arterial bifurcation can be pro-atherosclerotic. Several studies report that genes associated with atheroprotection have shear stress responsive domains on their promoters and ultimately can decrease EC apoptosis and leukocyte transendothelial migration. Among these laminar shear stress-induced genes are superoxide dismutase (SOD) and endothelial nitric oxide (NO) synthase, both leading to increased nitric oxide bioavailability. In addition, laminar shear stress inhibits the expression of adhesion molecules, e.g., VCAM-1, and possibly the activation of pro-apoptotic factors, e.g., caspases. Moreover, laminar shear stress downregulates the chemokine monocyte chemotactic protein-1 (MCP-1/CCL2) gene expression by ECs, potentially maintaining atherosclerotic lesion-free areas under steady flow. In fact, this chemotactic cytokine, MCP-1, through the activation of its receptor CCR2, can induce migration of monocytes, lymphocytes, ECs, and VSMCs. Of note, all these cells express MCP-1 during atherogenesis or following balloon injury and can recruit other arterial cells to migrate into the intima as well as recruit leukocytes from the blood. Both transgenic and knockout mice for MCP-1 and CCR2 have demonstrated a role for these molecules in the pathogenesis of atherosclerosis and intimal hyperplasia. Other chemokines have functions similar to MCP-1 but recruit and activate different classes of leukocytes to the arterial intima. For example, T lymphocytes migrate to the intima toward a concentration gradient of three other chemokines, inducible protein-10 (IP-10), monokine induced by IFN-γ (Mig), and IFN-inducible T cell α-chemoattractant (I-TAC), all of which are induced by interferon-γ (IFN-γ), and bind the chemokine receptor CXCR3. Chemoattraction of mast cells, also found in the intima, is mediated by another chemokine, eotaxin, which binds to the CCR3 receptor. Once these leukocytes are resident in the arterial intima they undergo modifications that contribute to the potential development of the atherosclerotic lesions. Monocytes acquire the characteristics of tissue macrophages and express scavenger receptors, CD36, on their surface, which permit internalization of modified lipoproteins, causing a transition of macrophages to foam cells. Macrophages also secrete cytokines and growth factors, e.g., tissue factor (TF) and matrix metalloproteinases, that mediate the development of the atherosclerotic process. Transmigrated T cells within the arterial intima may encounter antigens, such as oxidized low-density lipoproteins (ox-LDL), and after activation these can produce cytokines that also modify the function of other resident cells. In addition, mast cells within the intima degranulate and release, among other factors, TNF-α and chymase. In summary, growth factors, proteases, and cytokines, which include several chemokines, play a crucial role in the transition to the atherosclerotic lesion.

Pathological intimal thickening is the first evidence of progressive atherosclerotic lesions. This stage is often referred to as an intermediate lesion and is poorly defined. Virmani et al. histologically described the pathological intimal thickening as a lesion with some lipid accumulation but no evidence of necrosis. A fibrous cap overlies the lipid area and is rich in VSMCs and proteoglycans. Macrophages and lymphocytes are sparse. At this stage, VSMCs may change their phenotype and function and switch from a so-called contractile to a synthetic phenotype, losing their differentiated function as their contractile filaments are replaced by endoplasmic reticulum and Golgi. Synthetic VSMCs proliferate and migrate in response to growth factors and cytokines, and also secrete extracellular matrix components and more growth factors, cytokines, and proteases in a vicious cycle. As the lipid core grows, activated leukocytes secrete proteinases that degrade the extracellular matrix and cytokines, such as interferon-γ (IFN-γ), that inhibit the deposition of collagen. This process results in a more definitive lesion, the fibrous cap atheroma, in which a necrotic core is present, with cholesterol, phospholipids, and triglycerides. At this stage the fibrous cap is a distinct layer of connective tissue that covers the lipid core. It is composed of VSMCs embedded in extracellular matrix, and is infiltrated with macrophages and lymphocytes. Lesions that are most likely to evolve toward rupture are those defined as thin fibrous cap atheroma (<65 μm thick). In this case the necrotic core is very large, with observed presence of vasa vasorum, hemorrhage, and/or calcification, and the fibrous cap has lost VSMCs, matrix, and the inflammatory infiltrate.

The most advanced stage of atherosclerosis, the lesion with thrombi, can be the result of three

different processes: rupture, erosion, and, less frequently, calcified nodulation. When an atherosclerotic plaque ruptures, a defined area of the fibrous cap is disrupted, and coagulation molecules that are present in the blood may come into contact with TF produced by the leukocytes in the lipid core, which causes thrombosis. If the local conditions are prothrombotic and profibrotic, the formation of an occlusive thrombus can cause an acute coronary event. Alternatively, factors associated with the thrombus, such as thrombin, platelet-derived growth factor (PDGF), and transforming growth factor-β (TGF-β) may mediate the healing and induce collagen deposition and VSMC proliferation, leading to an advanced fibrous and often calcified plaque. Plaque ruptures are the most common cause of death in young men (<50 years of age) and in older women (>50 years), and are found in the 60% of people dying of sudden luminal thrombi. The type of rupture caused by erosion is defined as the area in which the endothelium is absent, with consequent exposure of VSMCs and extracellular matrix. In some cases the fibrous cap rupture results in a lesion with a calcified nodule. The origin of this kind of lesion is not well known, and it occurs more frequently in areas of the arteries of maximal torsion stress. Finally, examples of lesions not necessarily associated with thrombi are fibrocalcific plaques, characterized by a thick fibrous cap and extensive accumulation of calcium in the intima. The necrotic core, if present, is very small, pointing to these lesions as a potential result of healing after plaque rupture. More commonly, healed plaques show a disrupted fibrous cap filled with VSMCs, proteoglycans, and collagen.

Inflammation: A Target of Novel Therapeutic Interventions for Atherosclerosis

The most commonly accepted hypothesis for the initiation of atherosclerosis assigns the most prominent role to lipids. LDL cholesterol is undoubtedly an important contributor and may be the permissive factor for atherogenesis. In this regard, it is important to note that the average levels of cholesterol in Western countries most probably exceed the true normal levels for our species, as suggested by evidence in animal models and humans in agrarian societies. With this consideration in mind, cases of individuals with proven coronary artery disease and with normal levels of cholesterol exist, and therapies that target LDL cholesterol are effective in decreasing coronary events by one-third over 5 years of treatment.

Novel risk factors currently under consideration are lipoprotein (a), oxidant stress by angiotensin II (AngII), and infectious agents. Studies that have addressed the role of infectious agents in atherosclerosis, of which *Chlamydia pneumoniae* has been the primary focus, thus far have given inconclusive results. New classes of atherosclerotic drugs include inhibitors of hydroxymethylglutaryl coenzyme A (inhibitors of HMG CoA reductase, or statins), angiotensin-converting enzyme inhibitors (ACE), and angiotensin receptor blockers (ARBs).

Statins inhibit HMG CoA reductase, the enzyme that catalyzes the rate-limiting step in the synthesis of cholesterol. In addition, statins also have a pleiotropic effect and can alter many cellular processes, at least at high concentrations *in vitro*. This is due, in part, to the inhibition by statins of polyisoprenoids, other bioproducts of the cholesterol synthesis pathway. When these polyisoprenoids are linked to proteins, they generate prenylation and alter the protein function. One target of prenylation is the Rho family of small G-proteins, important downstream molecules in receptor-mediated signals that control cell migration and proliferation. Therefore, the inhibition of prenylation by statins has a direct effect on cellular functions, independent of lipid lowering. This inhibition of cellular migration and proliferation is especially important with respect to VSMCs and their role in the atherosclerotic plaque stability. It is important to note that the inhibition of VSMC proliferation by statins is still controversial: as plaque progression occurs, this inhibition could be beneficial by interfering with development of the lesion, while in the established atherosclerotic lesion the lack of VSMCs may adversely alter plaque stability. Other interesting effects of statins observed in animal models are to decrease TF expression by macrophages and to increase NO synthase expression.

Recent clinical trials suggest that blocking AngII by inhibiting its activator ACE or its receptor-mediated signals using ARBs can be beneficial beyond the effect on blood pressure. Data from the Heart Outcomes Prevention Evaluation (HOPE) trial show that ACE inhibition therapy, at doses that had little effect on blood pressure, significantly reduced cardiovascular events. Blocking the angiotensin type I receptor (AT_1) by using ARBs can be very selective and resulted in a better side effect profile compared to ACE inhibitors as shown by recent clinical trials, e.g., the Valsartan in Acute Myocardial Infarction Trial (VALIANT), among others. One of the targets of ACE inhibition or ARBs could be the ability of AngII to produce pro-inflammatory molecules such as IL-6 and MCP-1. Furthermore, ACE inhibition in

rabbits with experimental atherosclerosis reduces the activation of the transcription factor NF-κB, an upstream factor in the production of IL-6 and MCP-1.

Chronological development of pre-atherosclerotic lesions occurs with advancing age. Intimal xanthomas have been observed in individuals in the first and second decades of life, preatheromas in the second, and fibroatheromas in the third decade and later.

The remainder of this article reviews the current knowledge regarding the effect of aging on the arterial wall and its emerging role as an independent risk factor for atherosclerosis as well other CVDs.

Advancing Age Is the Major Risk Factor for Vascular Disease

The incidence and prevalence of CVD increases exponentially with advancing age, both clinically and subclinically, i.e., silent coronary atherosclerosis, and have an important impact on morbidity and mortality in Western society (**Figure 3**). Epidemiologists, gerontologists, and vascular biologists have teamed up to define the risk of the aging process–exposure time interaction with respect to the development of CVD in apparently healthy humans and animal models.

Several explanations for the role of arterial aging in atherosclerosis have been postulated. One is that aging, per se, is a disease, but the fact that some persons age without evidence of arterial diseases does not support this hypothesis. Another is that the dose of other risk factors for the development of age-associated arterial diseases progressively increases with advancing age, and moreover that aging is associated with increased exposure time to such risk factors. A distinct but somewhat related view is that the structure and function of the cardiovascular system undergo age-associated changes that alter the substrate on which pathophysiological disease mechanisms take place. Thus, in older persons mechanisms that underlie age-associated changes in arterial structure and function become partners with mechanisms linked to arterial diseases. This interaction is further complicated by the genetic background, lifestyle, and environment of each individual.

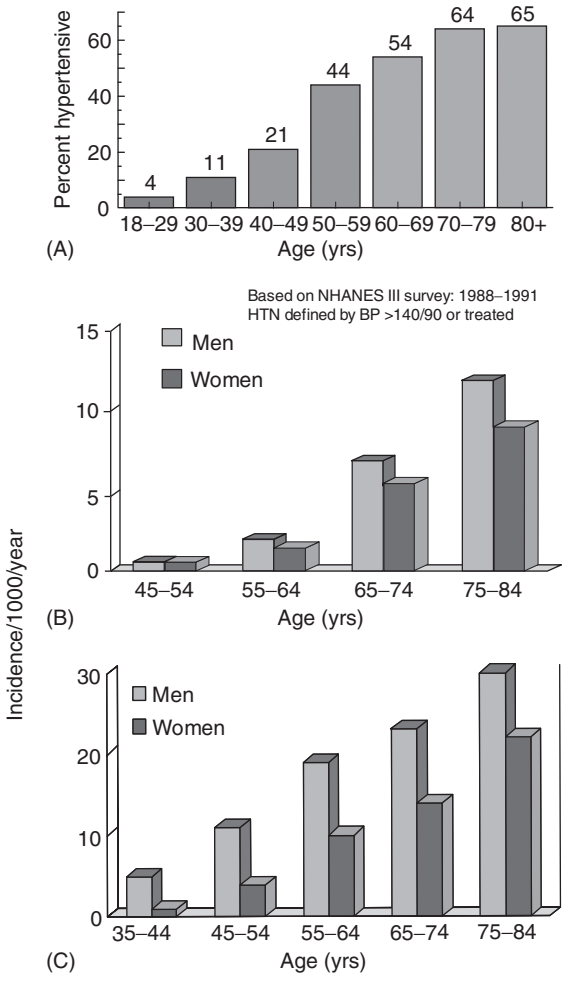

Figure 3 The incidence and prevalence of cardiovascular disease increase with aging. (A) Prevalence of hypertension defined as systolic blood pressure (BP) $\geqslant$140 mmHg, diastolic BP $\geqslant$90 mmHg, or current use of medications fro treatment of high BP. Data are based on National Health and Nutrition Examination Survey III (1988–1991), Burt VL, Whelton P, Roccella EJ, et al. (1995) Prevalence of hypertension in the US adult population: results from the Third National Health and Nutrition Examination Survey, 1988–1991. *Hypertension* 25: 305–313. (B) Incidence of atherothrombotic stroke (per 1000 subjects per year) by age in men (light gray bars) and women (dark gray bars) from the Framingham Heart Study. Data from Wolf PA and Lewis A (1993) Conner lecture: contributions of epidemiology to the prevention of stroke. *Circulation* 88: 2471–2478. (C) Incidence of coronary heart disease by age in men (light gray bars) and women (dark gray bars) from the Framingham Heart Study. Data from Kannel WB, Wolf PA, and Garrison RJ (eds.) (1987) *Framingham Study: An Epidemiological Investigation of Cardiovascular Disease*, Section 34. NIH Publication No. 87-2703. Bethesda, MD: National Heart, Lung and Blood Institute.

Human Arterial Structure and Function: Age-Associated Changes

Increased Intimal Thickening as a Risk Factor for Atherosclerosis Longitudinal studies are a powerful tool for understanding the aging process. These studies follow apparently normal participants that are selected for the absence of disease over many years and keep track of their health status and lifestyle habits, which could influence the onset of age-associated diseases. Among these studies, the Baltimore Longitudinal Study on Aging (BLSA), has contributed to characterizing multiple aspects of the effect of aging on cardiovascular structure and function in a single study population.

In humans, large elastic arteries, i.e., aorta and carotid arteries, thicken and show increased dilatation with advancing age, and this remodeling is observed in postmortem analysis to be present mainly in the intima. The carotid wall intimal media (IM) thickness increases two- to threefold from 20 to 90 years of age, but heterogeneity among older individuals is very prominent. Data show that this remodeling occurs in the context of EC dysfunction, but no detailed information is available yet.

IM thickening at a given age predicts the presence of silent coronary artery disease (CAD) (**Figure 4B**), which often progresses to clinical CAD. Interestingly, the difference in IM thickening between young and old individuals in the absence of CAD exceeds the difference among older persons free of disease and those with evidence of CAD. These data from the BLSA suggest that IM thickening is a risk factor for atherosclerosis and is strongly influenced by aging. Several other studies on individuals not previously screened for the absence of occult CVD have also shown that increased IM thickening is a predictor of cardiovascular events. Consequently, the degree of risk varies with the degree of thickening (**Figure 4C**), and the IM thickening is as potent a predictor of the development of disease as other traditional risk factors, such as LDL levels, diabetes, smoking, blood pressure, and atrial fibrillation (**Figure 4D**).

It is important to note that age-associated IM thickening also occurs in nonhuman primates and rodents in the absence of lipid infiltration or other evidences of atherosclerosis (**Table 1**). Therefore, the excessive IM thickening in humans with advancing age, in the absence of evidence for plaque, is not necessarily a manifestation of early atherosclerosis, but rather is attributable to arterial aging. This, combined with age-associated endothelial dysfunction, vessel stiffening, and changes in arterial pulse pressure, may lead to age-associated diseases. Thus, in Western societies the atherosclerotic plaque is activated by additional risk factors such as hypertension, smoking, dyslipidemia, diabetes, diet, and genetic factors that interact with aging of arteries. Evidence in rabbits and nonhuman primates supports this hypothesis: in these models an atherogenic diet that leads to equivalent increases in plasma lipids for a fixed period of time causes more severe arterial lesions in older than in younger animals.

Arterial Stiffening and Pressure During aging the IM thickening in both men and women is accompanied by increased stiffness of central arteries (measured as pulse wave velocity [PWV]), a decrease in compliance, and luminal dilatation. Arterial stiffening, reflected as an increase in PWV, is often

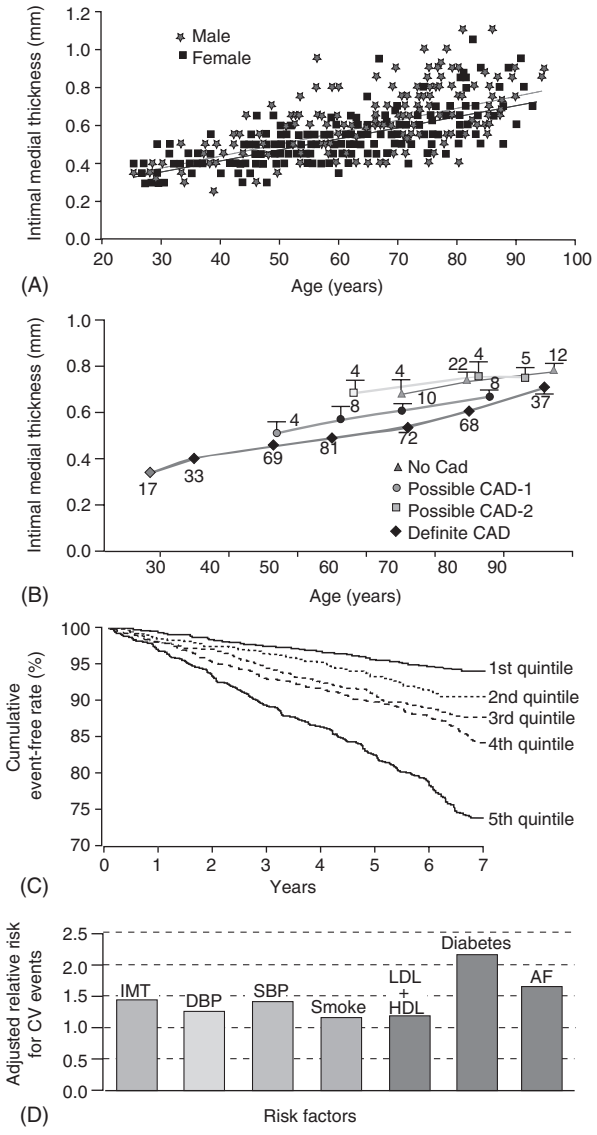

Figure 4 (A) The common carotid intimal medical thickness in healthy BLSA volunteers as a function of age. Data from Nagai Y, Metter J, Earley CJ, et al. (1998) Increased carotid artery intimal-medial thickness in asymptomatic older subjects with exercise-induced myocardial ischemia. *Circulation* 98: 1504–1509. (B) Common carotid intimal medial thickness as a function of age, stratified by coronary artery disease (CAD) classification. Reprinted from the same article of panel A. (C) Common carotid intimal medial thickness predicts future cardiovascular events in Cardiovascular Health Study (CHS). (D) Comparison of the associations of age- and sex-adjusted risk factors with the combined event of stroke or myocardial infarction in Cox proportional hazards models in the CHS study. Note that intimal medial thickness is a potent risk factor for future cardiovascular events. IMT, intima-media thickness, per 1 SD; DBP, diastolic blood pressure, per 11.3 mm Hg; SBP, systolic blood pressure, per 21.5 mm Hg; LDL, low-density lipoprotein; HDL, high-density lipoprotein, per 1 SD; Diabetes and AF, atrial fibrillation, per yes vs. no. C and D are reprinted from O'Leary DH, Polack JF, Kronmal RA, et al. (1999) Carotid-artery intima and media thickness as a risk factor for myocardial infarction and stroke in older adults: Cardiovascular Health Study Collaborative Research Group. *New England Journal of Medicine* 340: 14–22, Massachusetts Medical Society.

Table 1 Arterial remodeling with aging and atherosclerosis

	Humans (> 65 yrs)	*Monkeys (15–20 yrs)*	*Rats (24–30 mo)*	*Rabbits (3–6 yrs)*	*Atherosclerosis*
Lumen dialation	+	+	+	+	?
↑Stiffness	+	+	+	+	+
Endothelial dysfunction	+	+	+	+	+
Diffuse intimal thickening	+	+	+	+	+
↑VSMC	+	+	+	+	+
↑Macrophages	+	−	−	−	+
↑T lymphocytes	+	−	−	−	+
↑Matrix	+	+	+	+	+
Lipid involvement	−	−	−	−	+
MMP dysregulation	+	+	+	+	+
↑CAM	?	?	+	?	+
↑TGFB	?	+	+	?	+
↑MCP-1/CCR2	+	+	+	+	+
↑NADPH oxidase	?	?	+	?	+
↓Nitric oxide bioavailability	?	?	+	+	+
↑Local ANGII-ACE	+	+	+	+	+

attributed to changes in the vascular media, such as increased collagen, reduced and fragmented elastin, and calcification. Increased PWV with aging has been observed in humans in the absence of atherosclerosis, but more recent data show that atherosclerosis and diabetes contribute to increased large vessel stiffness. Therefore, arterial stiffening may be mediated not only by matrix changes but also by EC dysfunction, observed in the aforementioned pathologies, and consequent compromised regulation of VSMC tone. It has been shown that endothelial function is altered from the sixth decade of life, concomitant with observed elevations in pulse pressure. Both elevated pulse pressure and PWV are now known to be independent risk factors for cardiovascular events. It has been hypothesized that nonenzymatic glycation of extracellular matrix components could lead to cross-linking of such molecules and participates in increasing arterial stiffness in aging and diseases. For example, nonenzymatic cross-linking of collagen due to advanced glycation end products (AGEs) results in stiffer fibers and consequently less distensible old arteries, in which the resident cells, ECs and VSMCs, have modified migratory and proliferative capacities. Of note, a new thiazolium derivative, ALT-711, that is able to break AGE-derived cross-linking, has an effect in reducing age-associated arterial stiffness and compliance in rats, nonhuman primates, and humans.

Age-Associated Molecular and Cellular Changes within the Arterial Wall

Increasing data support the notion of age-associated arterial remodeling as an inflammatory response that creates a metabolically active environment where diseases can flourish. Age-associated arterial remodeling shows similar characteristics at the cellular and molecular levels in all species, from rodents and nonhuman primates to humans (see **Table 1**). As noted, the mechanisms involved in this remodeling likely confer upon arterial aging the status as the major risk factor for arterial diseases. Specific facets of age-associated remodeling include luminal dilation, thickening of the intimal and medial layers with cellular and extracellular matrix reorganization, increased stiffness, and endothelial dysfunction (**Table 1** and **Figure 5A**). Studies have shown that diffuse intimal thickening with aging is characterized by accumulation of fibronectin, collagen, and VSMCs, with an increase in matrix metalloproteinase-2 (MMP-2) expression. In addition, aortic intracellular adhesion molecule (ICAM) and TGF-β1 expression markedly increase with age and localize to MMP-2-positive staining areas. Arterial aging is also characterized by an increase in NAD(P)H oxidase activity, reactive oxygen species (ROS) production, and a reduction in NO bioavailability (**Figure 6** and **Table 1**). Moreover, increased arterial levels of pro-inflammatory cytokines, such as MCP-1, TNF-α and IL-6, accompany aging.

Several of the molecules listed above that are changed with advancing age within the arterial wall are under the control of the AngII signaling system (**Figure 6**). Aortic ACE activity is increased in rodents and non-human primates with advancing age. Moreover arterial AngII itself increases in these animal models and colocalizes with ACE and MMP-2. Recent data show that other components of the AngII system are also changed with age,

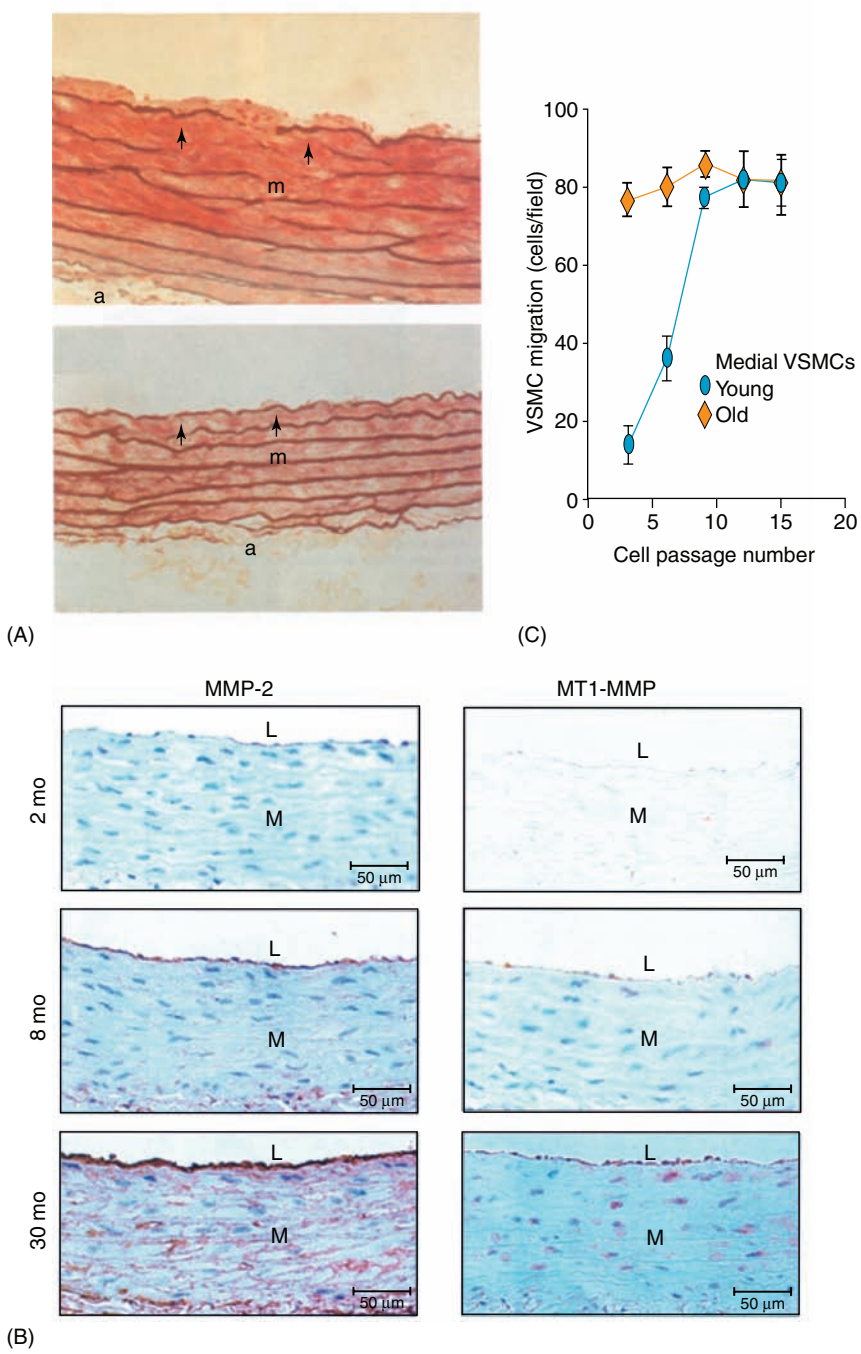

Figure 5 (A) Morphometric changes in the aortic wall of rats showing significant aortic intimal thickening in old rats (upper), as compared with young rats (lower). m, media; a, adventitia. Arrows show the internal elastic lamina. (B) Representative aortic sections from 2-, 8-, and 30-month-old rats stained with an antibody against MMP-2 and MT1-MMP, a tissue activator for MMP-2. The antibody stains brown. L, lumen; M, media. (C) Chemotaxis in response to a PDGF gradient is increased in early passage VSMCs from the aortic media of old rats compared with those from younger rats. VSMCs within the older aorta are primed to respond to the growth factor. Reprinted, and replotted in the case of panel C, from Lakatta EG (2003) Arterial and cardiac aging: major shareholders in cardiovascular disease enterprises: part III: cellular and molecular clues to heart and arterial aging. *Circulation* 107: 490–497.

and, in particular angiotensinogen and AngII receptor type 1 (AT1R), are increased. Of note, chronic administration of ACE inhibitors ameliorates or delays some aspects of age-associated arterial changes, such as intimal thickening and matrix remodeling. Thus, the local AngII system may play an important role in the arterial remodeling that accompanies aging.

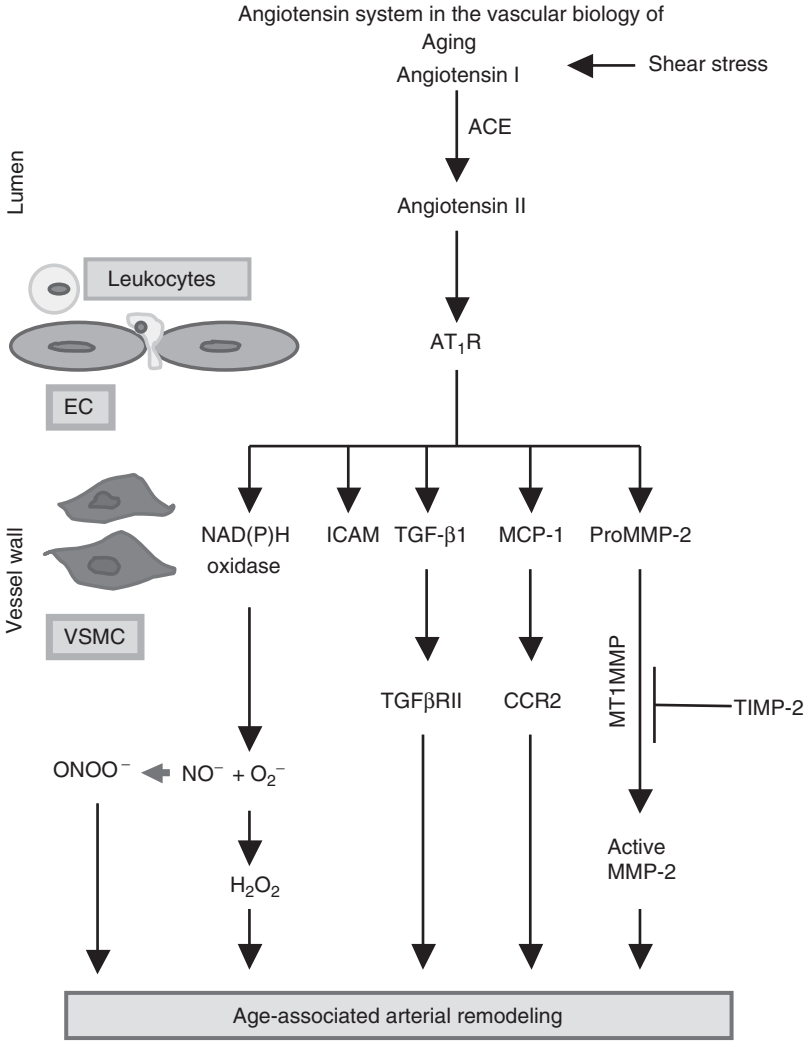

Figure 6 The potential role of the local angiotensin system in the vascular biology of aging. Schematic diagram of the angiotensin pathway-associated molecules that have potential role in the aging vascular remodeling.

Vascular Smooth Muscle Cells

Studies in rodents show that the structural and biochemical changes that occur within large arteries with aging are accompanied by a shift of the VSMC phenotype from the contractile to the synthetic state. This less differentiated state of VSMCs is characterized by an increased proliferative and migratory responsiveness to growth factors, as described in the case of the VSMCs that participate in the atherosclerotic plaque development. Early passage VSMCs isolated form older rats, for example, show exaggerated migratory capability in response to factors such as PDGF-BB, while cells from the aorta of young animals require many more passages in culture to give a similar response (**Figure 5C**). Synthetic VSMCs are thought to migrate from the media, invade the internal elastic lamina, and populate the intima, contributing to the process of the thickening. The involvement of cells from the circulation or resident ECs or VSMCs that undergo transdifferentiation to a VSMC phenotype, expressing characteristic markers, e.g., α-SMA, have not been demonstrated yet but represent a potential mechanism for the age-associated increase in VSMCs. Of note, while inflammatory cells are not detected in the arterial wall of rat, rabbit, or monkey (**Table 1**), VSMCs and ECs in the aged intima secrete inflammatory molecules. Among those factors, chemokines can affect migration and proliferation of VSMCs, ECs, or macrophages. One chemokine known for its crucial role in atherosclerosis, MCP-1, is also elevated in the plasma of older persons in the apparent absence of cardiovascular disease. Interestingly, recent studies have shown that MCP-1 is also upregulated in the aged rat aortic wall and regulates VSMC functions,

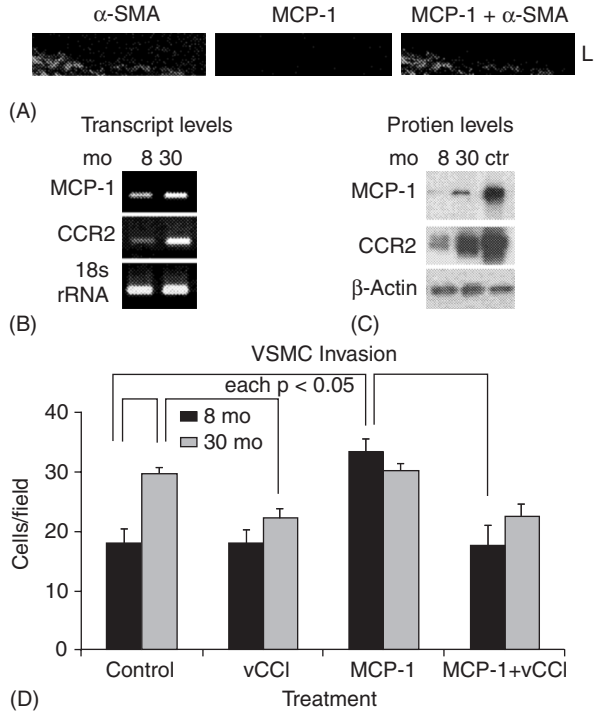

Figure 7 (A) Aortic cellular components associated with MCP-1. Immunofluorescence: double staining. MCP-1 (red, middle panels) increases in the rat aorta with age and localizes mainly in the intima. The left panels show the staining with a VSMC marker, α-SMA (green, upper panels), and an EC marker, CD31 (green, lower panels). The merged images show that MCP-1 staining colocalizes with CD31- and α-SMA-positive areas, as indicated by the white arrows (upper and lower right panels, yellow). L, lumen; M, media. (B and C) CCR2 and MCP-1 transcript and protein expression increase during aging *in vivo*. (B) A representative agarose gel showing the amplified cDNA fragments by real time PCR analysis, normalized to the expression of rRNA 18 s. (C) Representative Western blot analysis on protein extracts from rat aortae. CTR represents 50 ng of recombinant MCP-1 (upper panel) or protein extract from THP-1 monocytes cell line (lower panel), normalized to the level of expression of β-actin. m, months old. (D) MCP-1 pretreatment affects VSMC invasion. VSMCs isolated from old rat aortae show increased basal invasiveness in the absence of a chemoattractant, compared to cells from younger animals. Treatment with MCP-1 (50 ng/ml for 24 h) increases the basal invasion potential of young (8 months) VSMCs to the level of untreated VSMCs from old rats (30 months). The CCR2 antagonist vCCI (150 ng/ml) blocked this effect. Reprinted and remodeled from Spinetti G, Wang M, Monticone R, Zhang J, Zhao D, and Lakatta EG (2004) Rat aortic MCP-1 and its receptor CCR2 increase with age and alter vascular smooth muscle cell function. *Arteriosclerosis, Thrombosis, and Vascular Biology* 24(8): 1397–1402.

suggesting a role for this chemokine in age-associated vascular remodeling. Both the MCP-1 transcript and protein are increased within the rat arterial wall and are associated with ECs and VSMCs (**Figure 7A**). Treatment of young rat VSMCs with MCP-1 can increase their invasion ability in a receptor (CCR2)-dependent manner.

The migration of VSMCs is dependent at least in part on the activation of MMP-2 and degradation of the extracellular matrix in which these cells are embedded (**Figure 5B**). MMP-2 is secreted from ECs and VSMCs as an inactive enzyme. Its activation is dependent on the balance between membrane-bound activator (MT1MMP) and tissue inhibitor (TIMP-2), among other factors. Altered levels of these factors have been observed in the arterial wall of older rats, monkeys, and humans, leading to a marked increase in MMP-2 with aging.

Interestingly, MMP-2 is one of the enzymes responsible for the activation of TGF-β1, another growth factor increased within the aged arterial wall and a downstream product of AngII signaling (**Figure 6** and **Table 1**). Both circulating and arterial TGF-β1 increase with aging, and within the arterial wall TGF-β1 localizes mainly in the thickened intima in the same areas of MMP-2.

Endothelial Cells

Several reports have described EC dysfunction within the intima of older human and animal models. These cells are enlarged and show evidence of polyploidy and altered cytoskeletal arrangement and integrity that is reflected in their impaired ability to migrate and proliferate. The age-associated characteristics of ECs have been linked to both apoptosis and telomere shortening. In addition, adhesion molecule expression increases with aging in the rat aorta, and increased monocyte adhesion has been observed in the old rabbit vascular wall. Moreover, glycosaminoglycans are found in the subendothelial intimal layer. Glycosaminoglycans are important players in the regulation of vascular permeability and can affect the retention of macromolecules, e.g., ox-LDL. These altered features of ECs in older arteries can be partially responsible for the increased vulnerability to the development of atherosclerotic lesions of old arteries. In this regard it is interesting to note that ECs from older donors secrete increased levels of plasminogen activator-1 (PAI-1), an important prothrombotic factor. Furthermore, ECs from old vessels can secrete increased levels of AngII and endothelin, two known vasoconstrictor factors, supporting the role of AngII in the age-associated arterial remodeling. Parallel reduction in the expression of molecules with vasodilator properties, such as NO and prostacyclin 2 (PGI2), occurs with advancing age. The decreased NO bioavailability in the old rat, monkey, and human arteries results in reduced endothelial vasodilatation. Factors that can regulate the production of NO, directly or indirectly, e.g., endothelial NO synthase (eNOS) and NAD(P)H oxidase, are

also changed with advancing age. The latter is a major regulator of ROS generation in the vessel wall. The expression of its p22phox subunit is increased in the aged rat arteries, and the consequent increased ROS can then sequester NO and thus contribute to the diminished NO bioavailability (**Figure 6**). The activation of NAD(P)H oxidase is also induced by the triggering of the receptors of the family of the RAGEs by their ligands, AGEs. AGEs are proteins or lipids that have been irreversibly modified by non-enzymatic glycation and oxidation. These products increase with aging and have a potential role in age-associated arterial remodeling. AGEs can signal through the activation of the RAGEs. This activation mediates not only the aforementioned NAD(P)H oxidase activation, but also the production of TF and cytokines, i.e., IL-6 and MCP-1, the recruitment and activation of inflammatory cells, platelet aggregation, EC apoptosis, and VSMC proliferation and invasion. In addition to this function, AGEs have a well-known role in cross-linking collagen and several growth factors; this process is observed during aging even in euglycemia.

Arterial Stiffening

The increased arterial stiffening observed with aging is due, at least in part, to changes in an important component of the extracellular matrix: elastin. Elastin represents about 30% of the dry weight of the arteries, and the integrity of its fibers allows the correct stretch and recoil of the artery. Recently, several reports have demonstrated that elastin not only has a mechanical role in the arterial wall, but also can affect VSMC proliferation, migration, and vascular inflammation, since it acts as a growth factor and cytokine reservoir. When the elastin fibers are damaged, i.e., during aging, those molecules are released in the microenvironment and directly affect the VSMCs in the media. With aging, not only are the elastin precursor, tropoelastin, mRNA levels decreased, but also its degradation by MMP-2 is increased in parallel, leading to a net reduction of this important vascular tone modulator. As a result, old arteries show fragmented elastin (**Figure 6A**). Another mechanism potentially responsible for the increased stiffness is vascular calcification. Bone formation-associated genes, i.e., bone morphogenic protein-2 (BMP-2), osteopontin (OPN), and osteonectin, are all expressed with advancing age within the vessel wall, in addition to the bones. These factors bind calcium and can influence transdifferentiation of ECs and VSMCs to osteogenic and chondrogenic phenotypes.

Summary and Conclusions

In summary, molecular, cellular, and structural age-associated changes of large arteries resemble in many ways those observed in the development of an early atherosclerotic plaque (**Table 1**). But aging and atherosclerosis are two clearly separate conditions, as shown by the evidences in rodents and nonhuman primates, in which the same remodeling is present with aging in the absence of atherosclerosis. The pro-inflammatory condition observed in the arteries of such animal models, in the absence of leukocyte infiltration or lipid involvement, points to a new definition for inflammation in the context of the arterial wall as a physiological process to maintain homeostasis that involves inflammatory molecules affecting vascular cell functions. In humans the arterial changes during aging become part of the risk associated with advancing age of developing CVD and the increased susceptibility to traditional risk factors, e.g., lipid-rich diet, smoking, and diabetes. In conclusion, the age-associated pro-inflammatory phenotype of the arteries represents a highly responsive environment for the development of age-associated CVD.

See also: Cardiovascular System; Cellular Aging: Growth Factors and Cellular Senescence; Stroke.

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Attention

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Glossary

Attentional Capacity – The ability to process information quickly and/or the ability to process multiple stimuli or multiple tasks simultaneously.

Event-Related Potential (ERP) – A measure of electrical activity on the scalp triggered by a particular event.

Stroop Effect – When subjects take longer to name the ink color of a presented word when it is incongruent with the meaning of the word than when it is congruent.

Introduction

At any moment in time, our senses are flooded with a diverse array of sights, sounds, smells, tastes, and textures. We cannot deeply process all of these stimuli, nor would we want to (most are irrelevant to current goals). Therefore, it is imperative that we be selective in which stimuli we process and which we ultimately respond to. It is also imperative that we be selective in which tasks we perform on these stimuli. When hurriedly leaving the house, one needs to find the keys without being distracted by other potential tasks (e.g., reading the paper, cleaning the floor).

Control over cognitive processing, which is often loosely called 'attention,' becomes even more critical as we age. Sensory and motor processes can slow dramatically, further increasing the need for selectivity in which stimuli we perceive and respond to. Fortunately, many forms of attention are preserved with age. Other forms of attention, however, decline with age, resulting in severe performance problems. The purpose of this article is to review this important area of research, highlighting reliable generalities as well as unresolved issues.

Varieties of Attention

The study of attention is complicated by the fact that it is not a unitary construct. There are many different varieties of attention that are used in different situations and that are sensitive to different variables. In the present article, we concentrate on three important and widely studied varieties: attentional capacity, attentional selectivity, and executive task control.

The scientific study of attention is based on many years of theoretical and methodological development. Progress has been driven in part by the development of more precise quantitative methods and more sophisticated brain-imaging techniques. Despite this progress, not all theoretical controversies have been resolved. For example, there is still no consensus on whether there exist single or multiple pools of attentional resources, or how bottom-up (stimulus-driven) and top-down (goal-driven) processes combine to drive spatial attention. Controversies also abound in the study of aging and attention. One commonly held theory is that the declines in cognitive performance are due primarily to declines in processing speed. We will revisit this widely held but controversial hypothesis at several points. We conclude that although there are situations in which this proposal seems to hold, there are also replicated studies in which it does not.

Much of the research discussed here is based on the assumption that human cognition involves a series of distinct mental operations. Stimuli impinging on the sense organs (e.g., light on our retinas) are converted into neural signals, which then undergo a series of transformations, sometimes culminating in an observable response. Often these mental processes are modeled as discrete (strictly serial) stages, such as stimulus encoding, categorization, response selection, and response execution. This simplified stage framework allows one to ask whether and how specific stages are influenced by attention. One can also examine whether the effects of age are general (influencing all stages equally) or specific to certain stages.

Adult Age Differences in Capacity

The term 'attentional capacity' has been used in many different ways by many different researchers. Typically, it refers to the ability to process information quickly and/or the ability to process multiple stimuli or multiple tasks simultaneously. A multitude of approaches have been used to assess capacity and how it changes with age. In the following sections we review several prominent lines of research on capacity and the conclusions they afford.

Simultaneous Presentation Dual-Task Methodology

One way to assess an individual's mental capacity is to see how performance degrades as the number of tasks is increased. The classic method is to compare performance when two tasks are presented simultaneously to performance when only one task is presented. The net difference is often called the dual-task cost. Typically, the primary task (e.g., word recall or visual search) and the secondary task (e.g., tone discrimination: high- versus low-pitched tones) involve different sensory modalities. A common finding is that dual-task costs are substantial and increase as the difficulty of either task increases. These findings have been interpreted as evidence that the task demands exceeded the available attentional resources.

In aging research, simultaneous presentation dual-task studies have consistently shown larger dual-task costs for older than for younger adults. Furthermore, this difference increases as the secondary task difficulty increases. These results have been interpreted as evidence that older adults have decrements in attentional capacity. Craik and McDowd, for example, examined age differences in divided attention when participants performed a four-choice response time (secondary task) while simultaneously attempting to recall a list of words. Because dual-task costs were larger for older adults than for younger adults, Craik and McDowd concluded that older adults had fewer processing resources to allocate to word recall.

Although these conclusions seem reasonable, the interpretation of simultaneous presentation dual-task data is subject to certain conceptual problems. In this paradigm, people can trade performance between the two tasks (doing one better at the expense of the other). Such tradeoffs complicate interpretations of the data, especially when performance is reported for only one task (as is often the case). A further limitation of this paradigm is that the single-task and dual-task conditions are run in different blocks of trials. Consequently, these conditions differ not only in their capacity demands (dual-task vs. single-task), but also in the number of tasks that must be prepared and held in memory. The blocking of conditions also invites unwanted strategic differences between conditions (e.g., more effort or more cautiousness in dual-task blocks than in single-task blocks).

Sequential Presentation Dual-Task Methodology

Another dual-task methodology for assessing capacity is the sequential presentation method. The best-known and most widely used variant is the psychological refractory period (PRP) paradigm. In the PRP paradigm, two tasks (T1 and T2) are presented in close succession with a variable stimulus onset asynchrony (SOA). Participants are instructed to make speeded responses to T1 and T2 (denoted R1 and R2, respectively), and the response time (RT) for these two tasks is referred to as RT1 and RT2. Typically, RT1 is unaffected by SOA. A ubiquitous finding,

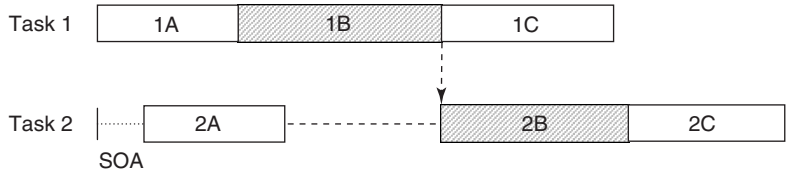

Figure 1 A central bottleneck model. This model assumes that the task 2 central processing stage cannot start until the task 1 central processing stage is completed. 1A, 1B, and 1C are, respectively, the prebottleneck, bottleneck, and postbottleneck stages of task 1. 2A, 2B, and 2C are the corresponding processes for task 2. SOA, stimulus onset asynchrony.

however, is that RT2 increases as SOA decreases (i.e., as temporal overlap between tasks is increased). This increase in RT2 has been termed the PRP effect.

PRP findings generally support the central bottleneck model, shown in **Figure 1**. This model hypothesizes that peripheral processes (encoding and response execution) can proceed in parallel for T1 and T2, but central processes (e.g., response selection) cannot. Thus, at short SOAs, T2 central processes must wait for T1 central processes to finish. This waiting produces the PRP effect on T2.

Sequential presentation dual-task methods (such as the PRP paradigm) address the two conceptual complications mentioned in the previous section on simultaneous presentation dual-task methods. First, sequential presentation (typically with same task order on every trial) tends to encourage a consistent dual-task strategy. Often, interference is restricted to T2, so that there is no performance tradeoff between tasks. Second, this approach uses several different SOAs between the presentations of task 1 (primary task) and task 2 (secondary task), mixed within a single block of trials. Mixing minimizes unwanted strategic differences between conditions. Because participants must always prepare for both tasks and hold both tasks in memory, this paradigm makes it possible to isolate true dual-task costs from the costs of preparing and maintaining two task sets in working memory.

Most studies of aging and PRP effects have shown evidence of larger PRP effects for older adults than for younger adults. However, the theoretical interpretations for this interaction differ widely across studies. Allen *et al.* proposed an executive control deficit that decreases the efficiency of switching between T1 and T2. Hartley and Little argued that older adults do not have an executive control deficit, but rather are less efficient in managing input interference and output interference. Finally, Glass *et al.* proposed that older adults exhibit poorer task coordination strategies. Although the Allen *et al.* and the Glass *et al.* viewpoints both emphasize executive control deficits, they are based upon opposing interpretations of PRP effects (the former is based upon Pashler's central bottleneck architecture and the latter is based upon Meyer and Kieras's executive process interactive control [EPIC] model). Consequently, although there is some agreement that older adults have difficulty in task coordination or time-sharing, there is no consensus as to the specific mechanisms involved.

Another major advantage of the sequential presentation method is that it provides an independent set of analytical tools to assess capacity – locus-of-slack logic. This logic allows one to determine which mental operations are capacity-limited (i.e., are subject to the processing bottleneck) and which are not. For instance, to determine whether a particular T2 process is subject to the bottleneck, one can manipulate the duration of that stage and measure the interaction with SOA. If the manipulated T2 stage occurs at or after the bottleneck, the effects should be constant across SOAs (an 'additive' interaction; see **Figure 2A**). If the manipulated T2 stage occurs before the bottleneck, the effects should decrease as SOA decreases (an 'underadditive' interaction, also known as 'absorption' of a factor effect into 'cognitive slack'; see **Figure 2B**). Thus, by examining whether a manipulation has additive or underadditive effects with SOA, one can determine whether the corresponding stage of T2 is subject to the bottleneck (capacity-limited).

Research using locus-of-slack logic with younger adults has revealed that perceptual processing (up to identification, in the case of letters) is generally not subject to the bottleneck. However, many subsequent processes are subject to the bottleneck, including response selection, memory retrieval, memory encoding, mental rotation, and lexical access.

With these findings in mind, it is interesting to ask whether the bottleneck has the same locus for younger and older adults. Given the hypothesis of reduced capacity for older adults, one might assume that they would have a longer list of bottleneck processes. In fact, the opposite appears to be true. Allen *et al.* reported a study in which T1 was tone discrimination and T2 was a lexical decision task (word vs. non-word). The difficulty of T2 lexical access was manipulated by choosing words with either high or low frequencies of use in the English

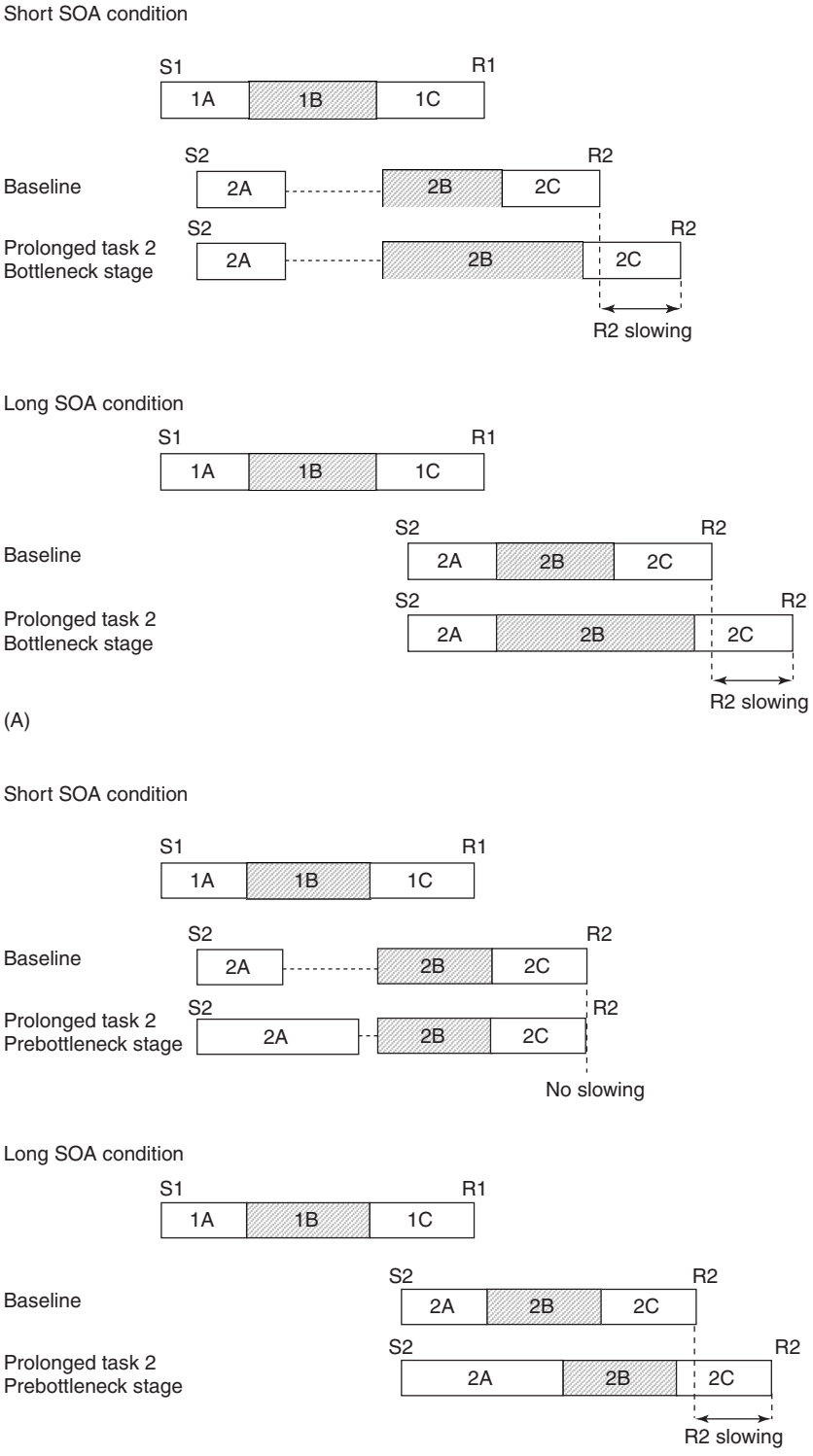

Figure 2 Predictions of a central bottleneck model. (A) Prolonging the central bottleneck stage in task 2 delays R2 at both short and long SOAs. (B) Prolonging the prebottleneck stage in task 2 delays R2 at long SOAs but not at short SOAs. 1A, 1B, and 1C are, respectively, the prebottleneck, bottleneck, and postbottleneck stages of task 1. 2A, 2B, and 2C are the corresponding processes for task 2. S1, stimulus for task 1; S2, stimulus for task 2; R1, response for task 1; R2, response for task 2; SOA, stimulus onset asynchrony.

language. Although word frequency effects on RT2 were roughly additive with SOA for younger adults, they were underadditive for older adults. These results suggest that lexical access was subject to the bottleneck for younger adults, but not for older adults. Furthermore, older adults actually showed shorter dual-task RTs than younger adults, after appropriately controlling for generalized slowing. Thus older adults actually demonstrated greater capacity than younger adults, at least with respect to the lexical access stage. One explanation for this surprising finding is that older adults have automatized lexical access due to their far greater cumulative experience with words.

An important question to address is why older adults appear to exhibit capacity decrements in simultaneous presentation dual-task paradigms yet can exhibit capacity advantages in sequential presentation dual-task paradigms. One possible explanation is that simultaneous presentation methods confound executive control effects (preparing for two tasks, deciding which to do first) and capacity effects (resource conflicts), whereas the sequential presentation methods allow one to isolate capacity effects. Perhaps much of the age deficit found in simultaneous presentation divided attention tasks is due to executive control effects rather than capacity effects. Consistent with this hypothesis, task-switching studies (see later section on executive task control) have often revealed evidence of executive control deficits in older adults.

Coactivation

In the dual-task studies described previously, each stimulus required a separate response. What would happen if multiple, redundant stimuli were presented, each pointing to the same response (as when using multiple clues to solve an entry in a crossword puzzle)? In a laboratory study, for example, participants might be asked to press a button if any stimulus in the display is the letter 'T'; will they respond more quickly when there are two Ts in the display, rather than just one? Typically, they do. This benefit of multiple targets is commonly known as a 'redundant signals effect' or just 'redundancy gain.'

One possible explanation for redundancy gain is that the redundant target stimuli are processed in parallel, and the first one to reach the central executive triggers the corresponding response. In other words, there is a sort of race between the stimuli. The more runners in the race (the more target stimuli), the faster the race will be completed (triggering a response). As an analogy, if a businessman sends two copies of a package, one by FedEx and one by UPS, he has two chances to get a quick delivery. This source of redundancy gain is typically referred to as 'statistical facilitation.'

According to the race model just described, each target stimulus is processed separately. In theory, even more efficient parallel processing would be possible if evidence from the different input channels could be combined together (as when a police detective combines multiple lines of evidence to conclude that a suspect is guilty). This summation of evidence is referred to as 'coactivation.' To provide evidence of coactivation, it is important to first show that the redundancy gain exceeds the amount of statistical facilitation that could be produced by a race between separate processes. Miller's 'race model inequality' provides just such a test:

$$P(RT < t|S_1 \text{ and } S_2) \leq P(RT < t|S_1) + P(RT < t|S_2) \quad [1]$$

The race model inequality provides a very conservative test of the race model. It gives the maximum amount of facilitation that a race could produce under the most extreme assumptions (i.e., perfect negative correlation between target detection times). Despite the conservative nature of the test, violations of this inequality have been frequently observed (at least for simple tasks). In these cases, race models can be discarded in favor of coactivation models.

Coactivation effects are thought to arise from combined activations in decision stages. These are the very stages that Cerella, in an influential meta-analysis of age-related slowing, hypothesized to be at the core of age deficits. Accordingly, one might expect older adults to show less redundancy gain and less evidence for coactivation. In actuality, older adults tend to show larger redundancy gains than younger adults. In 2005, Bucur *et al.* specifically looked for evidence of coactivation in older and younger adults. This study used the original paradigm of Miller with a visual target (an asterisk) and an auditory target (a tone). Interestingly, older adults and younger adults both showed large violations of the race model inequality, suggesting that both groups benefited from coactivation. These results have now been replicated and extended to conditions in which targets were defined along two dimensions of a visual target (e.g., shape and color).

The preserved redundancy gain and coactivation in older adults suggest that they have not lost any capacity to process multiple targets in parallel. Note that this is the same conclusion reached by PRP studies using locus-of-slack logic. These findings contradict the widely held belief that age-related slowing is due primarily to reductions in capacity. We return to this issue in the conclusions section.

Capacity as Speed

According to one school of thought, the slowing of cognitive processing with advanced age is a direct consequence of a decline in processing capacity. One could argue that this statement is circular, though, because there typically is no independent measure of capacity other than processing speed. A way to sidestep this circularity problem is to simply assume that processing speed is synonymous with attentional capacity. Evidence in favor of this view comes from studies assessing statistical mediation using hierarchical regression, path analysis, or structural equation modeling (SEM). The critical finding is that processing speed (e.g., as measured by a digit-symbol substitution task) mediates dual-task performance.

Not all attention studies find that processing speed mediates age effects, however. Many studies continue to find age × task complexity interactions even after a measure of processing speed has been co-varied out. Furthermore, Allen *et al.* re-analyzed earlier data reported by Salthouse and colleagues using SEM techniques and showed that direct age effects persisted independent of effects mediated by a common factor (such as processing speed). Although the situation is complicated, there is now conclusive evidence that common factors in SEM aging research are not consistent across studies and that processing speed is not a parsimonious synonym for attentional capacity.

Neurophysiology

Neurophysiological measures provide a direct window into central nervous system (CNS) function (more so than RT and accuracy measures) and have been profitably used to assess capacity and other aspects of human attention. Three functional measures are widely used: (1) event-related brain potentials (ERPs), (2) positron emission tomography (PET) scanning, and (3) functional magnetic resonance imaging (fMRI). Whereas ERPs have good temporal resolution but poor spatial resolution, both PET and fMRI methods have poor temporal resolution but good spatial resolution. In some cases, researchers employ both ERP and fMRI techniques to simultaneously obtain good spatial and good temporal resolution (this is referred to as multimodal imaging).

The ERP is a measure of electrical activity on the scalp triggered by a particular event (e.g., the activity following a stimulus or the activity leading up to a response). Because the signal-to-noise ratio is low, many trials must be averaged together to produce reliable data. The resulting average waveform consists of a series of positive and negative deflections. Often this waveform is summarized in terms of the amplitude and location of the individual peaks (also known as components). The most investigated ERP component is the P300 (a peak in positive amplitude approximately 300 ms after stimulus onset), thought to primarily reflect encoding and categorization processes but not response processes.

ERPs have been used to study the effects of age on cognitive performance. Bashore *et al.* conducted a meta-analysis of studies that used P300 measures and RT measures for a group of simple cognitive tasks. They summarized the results using a Brinley plot of older adults' performance versus younger adults' performance. For RT, the Brinley plot showed a slope greater than one (1.27), but for P300 amplitude values, the Brinley plot showed a slope close to equality (0.95). This dissociation suggests that age-related slowing with more-complex tasks is due to response processes that take place after the central operations that produce the P300. Note that the P300 data did show an elevated intercept for older adults, suggesting an encoding decrement that was insensitive to task complexity.

Although ERPs have excellent temporal resolution, they have poor spatial resolution. When researchers are interested in the spatial locus of brain activity, they often utilize PET and fMRI. PET methods measure regional cerebral blood flow, whereas the blood oxygenation level-dependent (BOLD) response in fMRI measures oxygen uptake from small blood vessels that nourish neurons. PET methods are relatively invasive – they require either injection or inhalation of radionuclides and relatively long scanning times. fMRI methods are non-invasive and therefore have become increasingly popular compared with invasive methods.

In a study of age differences in attention, Madden *et al.* found that older adults in a dual-task condition showed greater regional cerebral blood flow in prefrontal cortex areas than did younger adults. These findings, which have been replicated in several other studies of executive control, have been interpreted as a compensatory mechanism on the part of older adults – recruiting prefrontal areas to make up for deficiencies in other brain areas. Similarly, Cabeza found that older adults show bilateral prefrontal symmetry in cortical activation, whereas younger adults show prefrontal lateral asymmetry. He concluded that older adults recruit neurons from both prefrontal hemispheres to compensate for less efficient encoding. In 2005, Springer *et al.* provided additional fMRI support for this hypothesis. For younger adults, higher levels of education were associated with greater medial temporal cortical activation; for older adults, higher levels of education were associated with greater prefrontal activation. These findings, along with those of Cabeza and

DiGirolamo *et al.*, suggest that older adults recruit prefrontal regions so that executive control can compensate for less-efficient peripheral processing.

In contrast to the many studies showing increased prefrontal activity in older adults, West reported evidence of prefrontal deficits in older adults. Part of this discrepancy might stem from changes in activity in subcortical areas connected to the prefrontal areas. Rubin, for example, suggested that neural pathways between the prefrontal areas and the basal ganglia resulted in basal ganglia-based deficits being mistakenly labeled as prefrontal deficits. Also, caudate nucleus and related subcortical areas appear to be involved in controlling psychomotor processing speed. The effects of age on these cortical–subcortical relations should be examined with imaging techniques before the seeming paradox between prefrontal deficits and more active prefrontal recruitment on the part of older adults can be fully understood.

Adult Age Differences in Selectivity

Thus far, we have focused on capacity, which is often operationalized as the ability to process multiple stimuli at the same time. In this section, we now turn to the issue of attentional selectivity, which is operationalized as the ability to process relevant stimuli while ignoring irrelevant stimuli. Most of the research discussed here concerns selection of visual stimuli, as when searching for a specific visual target among distractors (*see* Perception). Researchers often attribute the enhanced processing of targets to the application of 'spatial attention' (often described as a 'spotlight') to the location of the target object. There is still disagreement, however, regarding whether selective attention is directed to spatial locations or to entire objects.

A distinction is often made between two qualitatively different modes of selection: top-down (directed by the observer) and bottom-up (drawn by stimuli in the environment). Bottom-up selection is often referred to as 'attention capture.' It has been shown that certain salient visual cues, such as a flash of light, can automatically pull spatial attention toward their location. It is considered automatic (not initiated by top-down mechanisms) because it occurs (1) very quickly (perhaps in less than 100 ms) and (2) even when the observer knows with 100% certainty that the location could never contain a target. A central issue concerns how endogenous (top-down) and exogenous (bottom-up) control interact. A fairly general consensus is that even though bottom-up control of spatial attention is involuntary, it occurs primarily for stimuli that match top-down control settings. When looking for a red object (say, a red car in a parking lot), other red objects can capture spatial attention. When looking for a new object to appear (e.g., a person to come around a corner), any other abrupt visual onset can capture spatial attention.

Next we describe how selective attention changes as adults age. A common finding is that older adults show performances similar to those of younger adults when top-down guidance is used and general slowing is taken into account. However, in conditions where there is less top-down guidance, older adults may show poorer performance than younger adults even after controlling for generalized slowing.

Top-Down Guidance of Visual Selection

When searching for an object, it often helps to have advance information about the target (e.g., when looking for one's keys, it helps to know where they might be and what they look like). Research suggests that older adults are just as able (if not more able) to utilize this top-down guidance of visual search as younger adults. For instance, older adults are just as able to use spatial cues that narrow down the possible target locations. Older adults also can benefit just as much as younger adults from knowledge of the likely identity of a target.

An important question is why older adults benefit so much from top-down attentional control relative to purely bottom-up attentional control. One possibility is that top-down control allows older adults to take advantage of their greater expertise in attentional search from a lifetime of experience. An alternative explanation is that cuing and singletons simply make tasks easier and that age differences are lessened because task difficulty is lessened.

Visual Search

There is some evidence for age effects in visual search for a target among distractors. Rabbitt, for example, reported a card-sorting study (a type of visual search task) with younger and older adults in which he varied display size. As display size increased, older adults performed progressively more poorly relative to younger adults.

However, age differences in visual search are not always found. When tasks require searching multielement displays in both static (non-moving) and dynamic (movement) conditions (distributed attention), there are many cases in which older adults continue to show preserved selective attention. Kramer *et al.*, for instance, found efficient search for both younger and older adults in both static and dynamic conditions. Also, Atchley and Kramer found that older adults could search efficiently when

a depth dimension was added. Hahn and Kramer found that older adults were able to divide their attention between two target locations while ignoring distractor stimuli. Madden found that older adults took longer to process spatial cues and shift their attention across display locations, although this slowing does not necessarily reflect selective attention deficits, per se.

Inhibitory Control and Selection

Rabbitt's hypothesis that older adults exhibit a search deficit because they are more distracted by irrelevant stimuli than younger adults (a filtering deficit) was elaborated upon by Hasher and Zacks. These researchers proposed that the filtering deficit reflects a very general inhibitory control deficit. According to their theory, one consequence of this deficit is an increase in the amount of task-irrelevant stimuli stored in working memory.

This issue has been extensively investigated using the well-known Stroop effect. The Stroop effect is when subjects take longer to name the ink color of a presented word when it is incongruent with the meaning of the word (e.g., when the word 'green' is presented in red ink) than when it is congruent (e.g., when the word 'green' is presented in green ink). Older adults consistently show filtering decrements in Stroop tasks, which has been interpreted as evidence for inhibitory deficits.

It is possible, however, that some filtering problems in older adults are due not to inhibitory deficits, but rather to enhanced automaticity. For example, older adults' greater word-reading expertise (from a lifetime of practice) is likely to result in greater word activation and greater interference on a Stroop task, compared to younger adults. Interestingly, age differences in Stroop interference are strongly attenuated in a modified Stroop task in which the color and the word belong to separate perceptual objects (a color patch at one spatial location and a word at another). Thus, older adults do not have a problem inhibiting words when they are not the focus of attention. Kramer and colleagues found in a number of other filtering paradigms (e.g., negative priming and inhibition of return effects) that older adults do not show larger inhibitory control effects than younger adults. Finally, Allen *et al.* examined visual search in a two-position redundant signals paradigm using 'go'/'no-go' and two-choice tasks. A key prediction of an inhibitory control account of age differences in attention is that older adults should make significantly more false alarms on 'no-go' trials than younger adults. Contrary to this prediction, Allen *et al.* found no age differences in 'no-go' false alarms. They did, however, find age differences in 'go' misses. Although the inhibitory control model of age differences in attention is an intriguing hypothesis, it does not appear that age differences in selective attention are due to a general inhibitory deficit.

Adult Age Differences in Executive Task Control

At each moment, we face a wide array of stimuli, each of which may afford a wide array of tasks. Thus, executive control is needed not only for selecting relevant stimuli, but also for selecting relevant tasks – those that help us to achieve our current goals. People have a remarkable ability to flexibly reconfigure their mental task set in accord with changing task demands. Although impressive, this executive control is not without limits. Studies have repeatedly shown that performance declines when people switch between two tasks compared to when they simply repeat the task. This switch cost persists regardless of how much time people have to prepare.

The classical method of studying task switching is to compare the performance of pure task blocks and alternating task blocks. As a concrete example, a pure task block might include several repetitions of an addition task, whereas an alternating task block might contain an alternating sequence of an addition task and a subtraction task. Rogers and Monsell proposed an alternating runs paradigm. In that paradigm, two tasks ('A' and 'B') are performed in a mixed task block with a task sequence such as AABBAABB, etc. One advantage of this design is that task switches and task repetitions can be compared within a single block of trials. Studies using this paradigm with younger adults have consistently found relatively small switch costs with univalent stimuli (associated with only one task), but large switch costs with bivalent stimuli (associated with both tasks). Bivalent stimuli provide no reliable task cue and therefore place a heavy burden on internal task control (e.g., inhibiting irrelevant task sets and/or activating relevant task sets).

In this section we discuss the effects of age on executive task control. One important distinction in these studies is that between the costs of task switching (repeat vs. switch) and the costs of task mixing. Mixing costs refer to slower task repetition performance in mixed task blocks than in pure task blocks (task A only or task B only); presumably, they primarily reflect the cost of maintaining two task sets in working memory rather than just one.

Mixing Costs

Although younger adults tend to produce little or no mixing cost, older adults often produce relatively large mixing cost. This difference in mixing costs is generally much larger than would be expected based on generalized slowing alone. Kray and Lindenberger proposed that the increased mixing costs reflect general impairments in working memory. Mayr, however, provided evidence that mixing costs are maximized when the tasks share the same stimuli and the same responses. Accordingly, he proposed that older adults have a specific difficulty in updating their internal control settings (differentiating between tasks).

These findings have important implications for dual-task methodology. As noted previously, the simultaneous presentation method involves comparing dual-task blocks to single-task blocks. Thus, the costs of mixing are confounded with the costs of temporal overlap in processing (reflecting capacity). Given that mixing costs increase with age, they alone might explain why overall dual-task costs often increase with age. This consideration suggests that dual-task and single-task conditions should be mixed within a block, as in the sequential presentation method.

Switching Costs

Studies that isolated switch costs from mixing costs have yielded inconsistent results regarding the effects of age. Whereas a few studies have revealed age effects on task switching after taking generalized slowing into account, many others have not. Although the source of the discrepancy is unclear, there is some evidence that age effects are elevated for tasks that impose a high memory load.

Why do mixing costs generally increase with age even though switching costs do not? It is tempting to conclude that older adults have difficulty maintaining two task sets (due to reduced working memory capacity) but have no difficulty switching between them. Another (admittedly subtle) explanation, however, is that older adults do have difficulty task switching and that this difficulty spills over to task repetition trials as well. Consistent with this explanation, note that older adults' task switch performance is generally very poor. It is only when one compares this poor task switch performance to the also poor task repetition performance (in the same block) that there appears to be little net switch cost. In this view, supposedly sophisticated attempts to isolate switch costs from mixing costs can produce misleading results. Arguably the best way to assess overall executive task control deficits in older adults is to study the sum of switch costs and mixing costs (i.e., compare task switch performance with task repetition performance from pure task blocks).

Conclusions

In the introduction to this article we noted that attention is not a unitary construct – rather, it consists of several distinct abilities, such as capacity, attentional selection, and executive task control. It is perhaps not surprising, therefore, that unitary theories of attention and aging have not held up to further scrutiny.

Perhaps the most widely held view is that age differences in performance are mediated by processing speed (an operational definition of attentional capacity). Although processing speed clearly plays an important role, there are documented cases of age differences that are not mediated by processing speed. Further evidence against this view comes from findings of preserved capacity in older adults, demonstrated by locus-of-slack and coactivation studies. Thus, rather than simply alluding to a general common factor (speed), component cognitive processes (such as selective attention) must be taken into consideration.

Another widely held theory of age differences in selective attention is that older adults exhibit poorer inhibitory control (a filtering decrement). Although this approach does have some empirical support, there are many cases in which older adults did not demonstrate inhibitory control deficits. It appears that age effects are due not only to deficits in inhibition (filtering) but also to deficits in activation (focusing).

A third theory of age differences in attention is the frontal lobe decrement model, based upon the observation that older adults show loss of cerebral volume of the frontal lobes. The theory is supported by the finding of executive control deficits in certain task switching conditions. However, there is mounting evidence that older adults do not show frontal deficits. Both PET and fMRI imaging have revealed greater bilateral prefrontal lobe recruitment on the part of older adults, suggesting that older adults use greater frontal activation to compensate for decrements in other neural processing (e.g., temporal cortex processing). Perhaps, for older adults, part of what we refer to as expertise involves developing compensatory recruitment.

Since Rabbitt's pioneering work on age differences in attention, much has been learned. The bad news is that age-related performance declines in capacity, executive task control, and selective attention do occur under many task conditions. The good news, however, is that there are also many cases of

preserved attentional functioning. In fact, there are even documented cases of age-related improvement in expertise, automaticity, and top-down attentional guidance. Recognition of these positive influences of aging might lead to explanations for some of the lingering controversies in the study of aging and attention.

See also: Adaptation; Perception.

Further Reading

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Autonomic Nervous System

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Glossary

Adrenergic – Having the properties of epinephrine or norepinephrine (NE). Drugs that produce effects similar to those of epinephrine are said to be adrenergic, as are nerve endings that release norepinephrine and the cell surface receptors that bind NE and epinephrine.

Baroreceptor Reflex – A mechanism for minute-to-minute regulation of blood pressure (BP). Baroreceptors located in arteries of the upper body respond to a reduction in BP by signaling the brain to activate the sympathetic nervous system, thereby raising the arterial pressure.

Catecholamines – Any of various amines that function as hormones and neurotransmitters in the autonomic nervous system, most notably epinephrine, norepinephrine (NE), and dopamine (DA). The former British names for epinephrine and NE are adrenaline and noradrenaline.

Cholinergic – Having the properties of acetylcholine; refers to drugs that mimic acetylcholine (ACh), nerve endings that release ACh, and the cell surface receptors in tissues that respond to ACh.

Neurotransmitter – A chemical substance that is released from nerve endings when the nerve fires. The neurotransmitter diffuses across the small space of the synapse and binds to a receptor located on an adjacent cell, where it produces its physiological effect.

Postural Hypotension – Reduced arterial pressure in the upper body after rapidly standing upright.

Renin-Angiotensin System – A mechanism for longer-term regulation of blood pressure and plasma volume. A fall in arterial pressure or sympathetic nerve stimulation causes release of renin from the juxtaglomerular apparatus of the kidney. The enzymatic action of renin causes the formation of angiotensin II, a peripheral vasoconstrictor that stimulates the release of aldosterone, facilitating sodium and water retention by the kidney.

Introduction

The autonomic nervous system (ANS) controls involuntary, vegetative, and visceral functions, including heart rate, blood pressure (BP), the motility and secretion of the digestive system, the urinary bladder, and aspects of sexual function. Some of the major responses elicited by the ANS are listed in **Table 1**. The responses of the ANS are involuntary. In contrast, the somatic nervous system controls voluntary

Table 1 Autonomic responses in aging[a]

	Sympathetic response	*Parasympathetic response*	*Aging effect*
Heart			
S-A node	β_1 increased heart rate	**DECREASED HEART RATE**	β_1 response impaired
Conducting system	β_1 increased automaticity	**DECREASED AUTOMATICITY**	β_1 response impaired
Ventricles	β_1 increased force		β_1 response impaired
Blood vessels			
Arterioles	**α_1 CONSTRICTION**	—	—
Arteries	β_2 relaxation	—	β_2 response impaired
Veins	α_2 constriction	—	—
Eye			
Ciliary muscle	—	Contraction for near vision	—
Iris	α_1 pupillary dilation	**PUPILLARY CONSTRICTION**	—
Lung			
Smooth muscle	β_2 bronchorelaxation	Bronchoconstriction	—
Secretions	α_1 decrease; β_1 increase	Increase	—
Salivary glands			
Fluid and electrolytes	—	Increased secreation	—
Proteins	β increased secretion	—	—
Sweat glands			
Palms and soles	α_1 stimulation	—	—
General sweating	Cholinergic stimulation	—	Impaired sweating
Gastrointestinal tract	Decreased motility	Increased motility	Increased motility
	Contract sphincters	Relax sphincters	—
Hepatic glucose	α_1, β_2 stimulation	—	—
Output		—	—
Adrenal medulla	Catecholamine secretion	—	—

[a] Bold capitals indicate SNS- or PNS-predominant tone.

responses of skeletal muscle. Somatic impulses arise in the motor region of the cerebral cortex. Autonomic impulses arise in the spinal cord, brain stem, and hypothalamus. Autonomic impulses also receive higher control from the limbic region of the cerebral cortex.

There are three separate arms of the ANS: the sympathetic nervous system (SNS), the parasympathetic nervous system (PNS), and the enteric nervous system (ENS). The SNS and PNS are under central control and are distinct in details of their anatomy and biochemistry. They are also partially opposing in the nature of the physiological responses that they provoke. Activation of the SNS produces a state of arousal and readiness. The PNS generally governs digestive and secretory functions, and the ENS is a local nervous system within the gastrointestinal tract.

General Description of the ANS

Anatomy of the ANS

The motor neurons of the somatic nervous system arise in the spinal column, and their axons pass directly to skeletal muscle without synapsing. The outgoing fibers of the ANS also have their cell bodies in the spinal column, but before reaching the target organ, they synapse in one of the peripheral autonomic ganglia. Thus, the autonomic pathway from the spinal cord to target tissue consists of two neurons: one preganglionic and one postganglionic.

Sympathetic fibers emerge from the thoracic and lumbar regions of the cord and pass into one of the sympathetic chain ganglia, which are located close to the spine. Some fibers synapse in the chain ganglia. This results in the spreading of the impulse to other fibers both higher and lower in the chain. Other fibers pass through the chain ganglia uninterrupted and synapse in one of the two major peripheral sympathetic ganglia, the celiac ganglion and the hypogastric plexus. In general, the spreading of sympathetic impulses leads to a diffuse activation. Often, many sympathetic responses are elicited together. This is ideal for a system that produces the fight-or-flight state of arousal and readies the body for action. Blood pressure and heart rate are elevated; glucose is released into the blood; the pupils dilate and digestion is inhibited. One more feature of the SNS aids in its diffuse activation. Sympathetic fibers innervating

the adrenal medulla stimulate release of epinephrine and norepinephrine (NE) into the systemic circulation. These two hormones stimulate a variety of tissues expressing adrenergic receptors, including tissues that are not innervated. Sympathetic activation remains somewhat of a challenge to measure accurately. In older adults, several techniques are used to measure NE, including microelectrode implantation and sampling of 'arterialized' venous blood.

The organization of the PNS is simpler than that of the SNS. Parasympathetic neurons emerge with the cranial nerves or from the sacral region of the spinal cord. They pass most of the way to their targets before synapsing in ganglia that are located close to or are imbedded within the target organs. The postganglionic neurons are very short. The anatomy of the PNS is designed for discrete activation. Parasympathetic responses are often evoked singly. The ENS is composed of the myenteric plexus of Aurbach, which coordinates contractions of the gut, and the submucosal plexus of Meissner, which controls secretions. The ENS is under higher control from the ANS. Sympathetic stimulation decreases intestinal motility, reduces intestinal blood flow, and suppresses mucosal transport. Parasympathetic innervation promotes secretion of gastric acid and pepsin secretion, increases gastrointestinal motility, and stimulates water and electrolyte transport.

Neurotransmitters and Receptors of the ANS

There are three major types of synapse in the SNS and PNS: the adrenergic synapse, located in the target organs innervated by the SNS; the muscarinic cholinergic synapse, in the target organs innervated by the PNS; and the nicotinic cholinergic synapse, located in the ganglia for both the SNS and PNS. Consideration of the effects of age on the postsynaptic receptors located in these synapses is important for two reasons. First, changes in the receptors or postreceptor biochemical events play an important role in the impairment of some autonomic responses with age. Second, these receptors are the major targets for drugs affecting the ANS. Thus, the response to many drugs may also be altered with age.

Acetylcholine (ACh) is the neurotransmitter at both the autonomic ganglia and parasympathetic target organs. However, the postsynaptic receptors are different at these two sites. The ganglionic synapse is called nicotinic, and the PNS effector synapse is called muscarinic, based on the ability of the postsynaptic receptors to preferentially bind either nicotine or muscarine. NE is the neurotransmitter at sympathetic effector sites (*see* Neurotransmitter and Neurotrophic Factors). The postsynaptic receptor for NE may be either α- or β-adrenergic, based on the preferential binding of certain agonists and antagonists. Many clinically useful drugs have been synthesized to specifically stimulate or block α-adrenergic, β-adrenergic, and muscarinic cholinergic receptors. In some cases, the response to these drugs is altered in senescence; this is discussed later. Drugs that interact with the nicotinic cholinergic receptors in the autonomic ganglia do not see widespread clinical use. These drugs produce many undesired effects, as they affect both the SNS and the PNS.

Autonomic Responses and the Principle of Predominant Tone

As mentioned previously, the SNS and PNS often innervate the same tissues. The responses of these two arms of the ANS are opposing in some cases, but not in all. When both the SNS and PNS innervate the same tissue, one system may be more active at rest than the other. In such a case, either the SNS or PNS is said to exert a predominant tone. The most important examples of predominant tone are listed in **Table 1**. The terms 'resting tone' and 'intrinsic tone' are synonymous with 'predominant tone.'

An example of predominant tone is seen in the control of heart rate. Activation of the SNS increases heart rate, and activation of the PNS decreases heart rate. At rest, the PNS is active and the SNS is inactive. ACh is released in the heart and NE is not. As a result, the heart beats slower at rest than it might if there were no autonomic innervation. When the subject is exercising, the situation is reversed. The sympathetic drive is higher and the heart rate increases dramatically. Thus, the predominant tone to the heart is parasympathetic at rest and sympathetic during exercise.

Predominant tone is important in considering the actions of agonists (receptor stimulators) and antagonists (receptor blockers). Agonists mimic the effects of the neurotransmitter, directly stimulating the receptor, and thus will always produce a response. In contrast, antagonists are effective only when an agonist or neurotransmitter whose action can be blocked is present. As a result, antagonists may have little effect on tissues in which there is no predominant tone. Atropine (a muscarinic blocker) blocks the action of ACh in lowering heart rate. Propranolol (a β-adrenergic blocker) blocks the action of NE in elevating heart rate. Atropine markedly elevates heart rate in a resting subject, while propranolol has little effect on resting heart rate in the same individual (*see* Cardiovascular System).

Anatomic Changes in the ANS with Age

A number of global changes occur in the human nervous system with age. These changes affect the ANS as well as other parts of the nervous system. The weight and volume of the nervous system reaches a maximum at puberty and later begins a progressive decline beginning in middle age. Some areas are relatively spared, such as the parietal lobes and brain stem. In the peripheral nerves, there is a loss in fiber number and a loss of myelination. The number of neurons is reduced with age, although the extent of loss has been difficult to assess in humans. The remaining neurons have a reduced cell volume and fewer dendrites. The most reliable marker that has been identified for aging of the nervous system is the accumulation of the fatty brown pigment lipofuscin within the neuron. Lipofuscin is absent in the neurons of newborns. Its accumulation increases progressively until senescence, when 60–70% of neurons contain inclusions.

In human autonomic ganglia, there is an age-related increase in lipofuscin accumulation and neurofibrillary tangles and a decrease in catecholamine content, as assessed by norepinephrine fluorescence. The number of cells is preserved in ganglia, but there is a distinctive neuroaxonal dystrophy characterized by large (5–30 μm) swellings. The density of autonomic innervation has been difficult to study in humans, so we have to rely mainly on animal data. One human study found that sympathetic innervation of the posterior tibial artery is reduced with age. Animal studies are not in complete agreement, but suggest that the sympathetic innervation decreases in some tissues with age. For example, arteries are more affected than veins.

Functional Changes in the ANS with Age

Sympathetic Nervous System

Circulating Catecholamines Circulating NE is increased in humans with age and epinephrine is unchanged. Most of the NE that circulates in the blood derives from adrenergic nerve terminals. In contrast, all of the epinephrine derives from the adrenal medulla. NE released into the synapse either may be degraded, reabsorbed by the same nerve terminal that released it, or may spill out of the synapse and eventually enter the systemic circulation. The possible explanations for increased NE levels in the elderly include reduced clearance across the capillary bed and increased release from sympathetic nerve terminals. Most evidence points to the latter.

Circulating epinephrine and NE increase in response to a variety of stimuli, including exercise, standing upright, and a mental stress test. The increase in NE is exaggerated in the elderly, but the increase in epinephrine is not. Because the epinephrine derives from the adrenal medulla and the NE mainly from adrenergic nerve terminals, one can conclude that under a variety of conditions, NE release resulting from sympathetic nerve activity is increased in the elderly, especially elderly men. This can be confirmed by measuring sympathetic nerve activity more directly using the microelectrode technique; it is found to be increased in the elderly.

There are two reasons for the increase in the release of NE in sympathetic nerve terminals. First, sympathetic responses are impaired as a result of age in a number of important target tissues. It is thought that greater release of NE occurs in an attempt to get an adequate response from these failing target tissues. The second reason concerns the loss of sensitivity in the baroreceptors. When pressure increases in the carotid artery and some other vessels, those vessels expand, activating the baroreceptors, which in turn act to reduce sympathetic outflow. Reduced sympathetic outflow reduces heart rate and peripheral resistance, thereby correcting the original increase in pressure. In older individuals, the vessels are more rigid and do not stretch as much in response to pressure. Thus, decreased baroreceptor sensitivity contributes to elevated NE and may also contribute to hypertension in the elderly. The vasoconstrictor component of the baroreflex is as strong in the elderly as in the young, despite the likelihood that α-receptor response of the vessel decreases slightly with age.

β-Adrenergic and α-Adrenergic Responses In the heart, NE released from sympathetic nerves stimulates β-adrenergic receptors. These receptors mediate increases in heart rate and in the force of contraction. The impairment of these responses with age results in a reduced ability to increase cardiac output during exercise. Because cardiac output is a limiting factor in exercise, exercise capacity is also impaired. β-adrenergic stimulation of the heart is also required for the postural hemodynamic response, which is called into play when BP drops in the upper body, such as after standing up rapidly. Thus, decreased β-adrenergic responsiveness in the elderly contributes to postural hypotension, or an inability to maintain BP after standing up. The primary deficits with aging are a 90% loss of sinus node cells between the ages of 20 and 75 and an uncoupling of β-receptors in the myocardium from the intracellular signaling required to cause an increase in the force of contraction.

β-Adrenergic dilation of blood vessels is also impaired with age. Dorsal veins in the hands of elderly

subjects display reduced relaxation in response to the β-agonist isoproterenol after first being constricted with the α-agonist phenylephrine. The response to isoproterenol is reduced with age in terms of both maximum response and sensitivity. The inherent ability of the vessel to relax is not impaired with age, as shown by the fact that dilation in response to papaverine and nitroprusside is unchanged with age.

β-Agonists are useful in treating asthma because of their ability to open the airways by causing a relaxation of bronchial smooth muscle. Adrenergic fibers are associated directly with submucosal glands of the lung and bronchial arteries, but not bronchial smooth muscle. β-Agonists act indirectly by opposing the parasympathetic constriction of bronchial smooth muscle. Adrenergic fibers innervate parasympathetic ganglia and cause bronchodilation by inhibiting cholinergic output. Animal studies show that β-adrenergic bronchodilation is impaired in aging.

α-Adrenergic responses are impaired with aging in some but not all cases. In human arteries, α_1-stimulated constriction is unchanged with age. In human veins, the α-constriction is reduced with age. Both the β-adrenergic stimulation of the heart and the α-adrenergic constriction of veins contribute to the postural hemodynamic response. Because both responses are impaired with age, the elderly experience postural hypotension.

There is evidence in both animal and human studies that the SNS has a protective role against autoimmune disease. In mice, the chemical destruction of sympathetic nerve endings exacerbates various experimental models of autoimmune disease. The β-adrenergic agonist isoproterenol has a protective effect against these same models of autoimmunity. Thus, it is possible, although not proven, that reduced adrenergic responsiveness is involved in the increased incidence of autoimmune disease in the elderly.

Aging is accompanied by impaired temperature regulation, resulting in increased susceptibility to hypothermia and hyperthermia. Hyperthermia can result from reduced density of eccrine sweat glands although there is no deficit in sudomotor activity (sympathetic nerve activity leading to sweat glands). Hypothermia may result from a decrease in nonshivering thermogenesis. This impairment is due to a decrease in the quantity of brown adipose tissue, specialized adipose tissue that generates heat in response to β-adrenergic stimulation.

Parasympathetic and Enteric Nervous Systems

The predominant parasympathetic tone, or vagal tone, to the heart is reduced with age due to a decrease in the intrinsic sinus rate in the elderly and the resulting reduced need to 'brake' the heart. The reduced vagal tone can be seen in the response to atropine, a blocker of the muscarinic receptor present in parasympathetic nerve endings. Atropine produces a smaller increase in heart rate in the elderly than in young subjects. There is also direct evidence in animal studies that parasympathetic responsiveness of the heart is reduced with age. Bradycardia, or slowing of the heart, in response to cholinergic agonists is reduced with age.

Bronchoconstriction occurs due to contraction of bronchial smooth muscle in response to parasympathetic stimulation. Animal studies have shown that this response is exaggerated in senescence. The mechanism is a decrease in the content of acetyl cholinesterase, the enzyme that terminates the action of the neurotransmitter ACh. As a result, ACh released into the synapse has a more prolonged action.

Gastrointestinal (GI) function is impaired in the elderly, and certain aspects of this impairment suggest autonomic dysfunction. However, it is important to distinguish GI dysfunction due to aging from the side effects of medication. With aging, there is difficulty in swallowing, increased gastric emptying time, increased intestinal transit time, constipation, and reduced absorption of calcium and fat. The rat model has also shown reduced transport of water, sugars, and amino acids. The density of innervation of the enteric nerve plexus is reduced in senescence. Impairments in the ENS play a key role in the changes in GI function that accompany aging. There is a specific loss of intrinsic sensory neurons, with preservation of nitrergic neurons. Irritable bowel syndrome and other related conditions are thought to occur due to changes in the function of enteric neurons, based on animal models. Reduced parasympathetic responses in the GI tract result in reduced secretions and motility. These changes contribute to a number of problems that are more common in the elderly, including achalasia and pseudo-obstruction. Achalasia is a disorder of swallowing involving a failure of the lower esophageal sphincter to relax. This relaxation is mediated by a parasympathetic discharge of the vagus nerve, which is impaired with aging. Pseudo-obstruction is dilation of the large bowel in the absence of an obstruction and occurs almost entirely in the elderly (*see* Gastrointestinal System: Function and Dysfunction). The PNS controls salivary excretion of fluid and electrolytes. Xerostomia, or dry mouth, is common in the elderly. However, parasympathetic responses in the salivary glands are unchanged with age and do not play a role in xerostomia.

Changing Role of the ANS in Cardiovascular Responses

Control of Blood Pressure

Falls and the attendant risk of hip fracture are an important problem in the elderly. Postural hypotension increases the risk of falls by causing a transient cerebral hypoperfusion and is caused in part by autonomic dysregulation. Postural hypotension may be defined as a drop in systolic pressure of ≥ 20 mmHg or diastolic pressure of ≥ 10 mmHg, or symptoms of cerebral hypoperfusion within 2–5 min of standing. Postural hypotension occurs in approximately 30% of those 65 or older. The causes of postural hypotension in the elderly include an impaired postural hemodynamic response due to impaired β-stimulation of the heart, volume depletion, and the presence of certain drugs. Chronic hypovolemia is a frequent condition in the elderly, and patients with severe volume depletion may experience orthostatic hypotension despite normal autonomic reflexes. Studies have shown that volume expansion resulting from 6 months of endurance training is helpful in correcting orthostasis.

Postprandial hypotension is also a common problem in the elderly, with the greatest drop in BP occurring about 1 hour after eating. Carbohydrate meals produce the greatest drop. Postprandial hypotension results from the inability to compensate for vasodilation in the GI tract. After a meal, the plasma NE concentration should increase two- to threefold as a result of increased SNS activity; this response is blunted in the elderly. The clinical significance of postprandial hypotension is unclear. It may precipitate strokes and myocardial infarction. Postprandial hypotension is also a factor in producing postural hypotension. Additional susceptibility to postural hypotension and syncope come from the increased preload to the heart in aging. The latter causes an elevation of circulating atrial natiuretic peptide, which in turn causes increased excretion of water and sodium, resulting in decreased blood volume.

Exercise Performance

The increase in cardiac output that occurs during exercise is, in part, mediated by the SNS. During exercise there is an increase in heart rate, an increase in the force of contraction, and an increase in stroke volume. Shunting of blood to the skeletal muscle is accomplished by vasodilation in the muscle and vasoconstriction in other tissues. In the elderly, two key sympathetic responses are impaired: β-adrenergic stimulation of the heart and β-adrenergic dilation of arteries supplying skeletal muscle. The increase in cardiac output that occurs during exercise is rate limiting for the amount of exercise that can be performed before the anaerobic threshold is reached and lactic acid accumulation begins. Thus, autonomic dysfunction may limit exercise capacity in the elderly. This decline is also due to other factors, such as reduced cardiac reserve, peripheral circulatory factors, and reduced muscle mass (*see* Motor Control). A lifelong active lifestyle may play an important role in preserving cardiac ANS responses and baroreflex sensitivity in older people.

Autonomic Dysfunction in Diseases Common in the Elderly

Primary autonomic failure is a degenerative disorder of the postganglionic neurons of the SNS. The symptoms, which include postural hypotension, impaired thermoregulation due to inability to sweat, low circulating catecholamines, impotence, and GI and urinary dysfunction, are most severe in the elderly. Any condition requiring extended bed rest in an older person can contribute to postganglionic sympathetic dysfunction in the lower extremities. This situation can lead to the inability to walk, thus further promoting deconditioning and risk of falls. It is suggested that the length of time one remains bedfast should be closely monitored with ambulation promoted early in the course of a condition, as appropriate.

Multiple system atrophy (or Shy-Drager syndrome) is a disease of preganglionic neurons of the SNS. There is degeneration in the sympathetic centers of the brain and in the lateral horn of the thoracic segments of the spinal column. Most of the same autonomic symptoms are seen in Shy-Drager syndrome as in primary autonomic failure, but there are often motor deficits as well, including marche à petits pas (the short-stepped gait). Circulating catecholamines are normal at rest, but fail to increase properly in response to a stimulus, such as rapid standing.

In Parkinson's disease, there is often autonomic dysfunction, with PNS dysfunction selectively occurring early in the course of the disease. Postural hypotension is a side effect of medication with l-dopa; the addition of a peripheral decarboxylase inhibitor, such as carbidopa, can eliminate this problem by confining the actions of l-dopa to the CNS and thus preventing the action of l-dopa on the autonomic ganglia. Other signs of autonomic dysfunction in Parkinson's disease, such as increased salivation, decreased frequency of bowel movement, and dysphagia, result from the disease process itself. Parkinson's disease is often accompanied by lesions of the spinal column similar to those that cause motor difficulties

in Shy-Drager syndrome. The impotence associated with Parkinsonism may have a basis in autonomic dysfunction. Abnormalities in thermoregulation are due to lack of sweating. Accidental hypothermia is a risk due to the absence of shivering.

In older patients with stable angina, research shows that the SNS plays a role in acute episodes of regional myocardial ischemia. Chronically elevated sympathetic nerve activity both increases metabolic demand and impairs myocardial perfusion.

Altered Autonomic Responses to Drugs Commonly Prescribed in the Elderly

Treatment of hypertension in the elderly is a double-edged sword. Effective lowering of BP often brings increased incidence of postural hypotension, a contributor to falls. α-Blockers often induce postural hypotension in the elderly, which may limit their use for treating hypertension and prostatic outflow obstruction. β-Receptor stimulation of the heart, which occurs during the postural response, is already diminished in normal aging. Thus, with the introduction of an α-blocker, both the α- and β-adrenergic arms of the postural response are now impaired. β-Blockers and diuretics also increase the likelihood of postural hypotension. Calcium channel blockers and angiotensin-converting enzyme inhibitors carry less risk.

The elderly have an increased susceptibility to adverse effects of tricyclic antidepressants. Pretreatment electrocardiogram (ECG) is necessary to determine whether or not QRS and QT prolongation coexist, an indication that the potentially lethal arrhythmia 'torsade de pointes' may develop when a tricyclic is given. Tricyclics such as amitryptyline exert their antidepressive effects by inhibiting neuronal reuptake of NE. These compounds also have α-blocking and anticholinergic effects. As a result of underlying autonomic dysfunction, the elderly are more susceptible to these side effects. Because tricyclics block α-receptors, they may on rare occasion cause sinus tachycardia in the elderly due to vasodilation and postural hypotension for the reasons described previously. The anticholinergic side effects of tricyclics include xerostomia (dry mouth), blurred vision, constipation, and urinary retention. The xerostomia is caused by an inhibition of parasympathetic stimulation of salivary fluid and electrolyte secretion. The blurred vision is caused by impaired contraction of the ciliary muscle of the eye, which is involved in accommodation for near vision. Newer SSRI antidepressants such as fluoxitine (Prozac), dertraline (Zoloft), and paroxitine (Paxil) work by inhibiting the neuronal reuptake of serotonin rather than NE. Whether the side effects of these drugs present a special problem in the elderly remains to be seen.

See also: Cardiovascular System; Gastrointestinal System: Function and Dysfunction; Motor Control; Neurotransmitter and Neurotrophic Factors.

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B

Balance, Posture and Gait

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Glossary

Adaptive Postural Control – Modifying sensory or motor response strategies in response to changing task and environmental demands.

Anticipatory Posture Control – Pretuning sensory and motor processes in expectation of postural demands based on previous experience.

Cognitive Processes – Higher level neural processes such as attention, motivation, and planning. It is difficult to make a clear distinction between higher-level perceptual/motor processing and cognitive processing, since there is a gradual transition and overlap between processing levels.

Postural and Balance Control – Regulating the body's position in space for the dual purposes of stability and orientation. Stability is the ability to maintain the position of the center of body mass (COM) within specific boundaries, or stability limits. Orientation is the ability to maintain an appropriate relationship between the body and the environment or task.

Sensory Strategies – Organizing sensory information from visual, somatosensory, and vestibular systems for postural control.

Introduction

Research on balance, posture, and gait in older adults has become a priority in the health-care field because data indicate that falls are a major threat to independence in older adults and an important contributor to fatalities. For example, it has been shown that nearly one-third of adults over the age of 75 experience at least one fall per year, and 6% of these adults sustain fractures as a result. Research on balance and gait in the older adult has focused on (a) determining whether there are specific neural and musculoskeletal subsystems that show a decline with aging and (b) creating effective measures for the prevention and the rehabilitation of decline in balance function with aging. Several approaches have been used in the past to study and assess balance and locomotor skills in the elderly from both a research and a clinical perspective. Traditionally, balance control was studied from a reflex perspective, and global methods of measuring balance were used. Since the 1990s, researchers have begun a systems approach to the study of balance in the older adult. This approach has the advantage of allowing clinicians and researchers to assess whether there is a decline in identified subsystems contributing to balance and gait.

Balance Control in Older Adults

Early Studies

Before reviewing studies on the changes in balance control in the older adult, we first define balance control and discuss the ways one can measure balance function. Balance control may be defined as the maintenance of a person's center of mass (COM) within his or her stability limits, which are defined as the person's base of support. Balance control thus indicates the ability to regulate one's static upright posture or to recover from unexpected threats to balance, such as the balance threat that occurs when standing on a bus that starts to move.

In addition to static balance control, an adult must also be able to maintain balance during many other daily activities, such as standing and walking. Maintaining balance during walking requires the integration of postural adjustments into the step cycle in order to allow safe forward movement. In this dynamic task the COM is not maintained within the base support, but moves along the medial border of the support foot. This integration of balance control into voluntary activities is essential to the accomplishment of most goal-oriented tasks and requires the ability to respond to constantly changing environmental and task demands.

Classically, the assessment and treatment of balance function in the older adult has been centered around global measures of balance abilities, such as the measurement of total body sway. For example, in 1963 Sheldon performed a study examining the degree to which sway during quiet stance changes across the lifespan. He found that subjects at both ends of the age spectrum (6–14 years and 50–80 years) showed significantly more sway during quiet stance than did young adults. **Figure 2** shows the sway path of representative subjects in each of the age groups tested.

Other research by Fernie and colleagues, which used a measure of both the amplitude and velocity of global body sway to assess the balance skill of institutionalized older adults, indicated that sway velocity is correlated with frequency of balance loss. Older adults who fell more than once per year showed higher velocities of sway when standing quietly when compared to those who did not fall.

Some of the earlier studies regarding balance function in the older adult often assumed that one could find a single cause of instability in an individual, such as peripheral neuropathy or postural hypotension. In addition, clinicians typically assessed balance function using a reflex model of balance control, limiting tests to evaluation of tendon reflexes, righting reflexes, and vestibulo-ocular reflexes, and predicting that with aging more 'primitive' reflexes would be released from inhibition. However, more recently research has indicated that a reflex framework of motor control is limited, since many other motor processes contribute to motor function.

It has become clear that for any given individual there are complex interactions between intrinsic factors related to the level of function of different nervous or musculoskeletal subsystems and also extrinsic environmental factors. It is important to study these interactions in order to clearly understand the factors that contribute to falls in the older adult. In one study, Campbell and colleagues observed a group of community-dwelling older adults for 1 year and documented all falls. The study concluded that reductions in physical activity, reduced proximal muscle strength, and reduced stability during quiet stance were all strongly linked with an increased risk of falling. They also showed a significant association between falls and arthritis of the knees, stroke, impairment of gait, hypotension, and the use of psychotropic drugs. The study concluded that multiple risk factors, many of which are remediable, are associated with most falls in older adults.

Though this approach has significantly improved our understanding of factors contributing to balance deterioration in the older adult, it is limited by the use of relatively broad categories to classify intrinsic factors related to falls, such as 'loss of stability while standing.' Such categories do not allow the identification of problems in specific subsystems that may be constraining balance abilities.

Systems Approach to Age-Related Changes in Balance

More recently, researchers have begun to use a new approach for testing balance control in older adults. This method, often called a systems approach, attempts to identify the relative contribution of deterioration in specific neural and musculoskeletal subsystems to a decline in balance function. The systems model of balance control has the advantage of being able to aid the clinician in evaluating the degree to which a decrease in the function of individual subsystems contributes to deterioration in balance and gait in the older adult. According to the systems model, balance stems from complex interactions among several factors, including a variety of neural subsystems, the musculoskeletal systems of the individual, and the task and environmental situations in which the individual is balancing and moving. The postural control system is usually identified as the neural and musculoskeletal subsystems that contribute to balance function.

In assessing balance function in the older adult from a systems model, one would evaluate both the neural components (motor systems, sensory/perceptual systems, adaptive systems, and cognitive systems) and the musculoskeletal components (muscle strength, range of motion of ankle, knee, and hip joints, and the vertical alignment of the body) that contribute to balance. The following section reviews research on changes in balance control in the older adult from the systems perspective.

Musculoskeletal Changes Many research studies have examined the extent to which postural components of the musculoskeletal system characteristics change with age. For example, it has been shown that strength of the leg muscle can show a reduction of 40% in young (30 years) vs. older adults (80 years). Whipple and colleagues showed that older adults with a history of falls (nursing home residents) show an even greater reduction in muscle strength, with ankle dorsiflexor strength being 14% of that of nonfallers. In addition, the muscle fatigues more rapidly and the rate of tension development is slower in older adults. Buchner and deLateur showed that there is an association between strength and physical function, with over 20% of the variance in functional status explained by relative muscle strength. Finally, spinal

flexibility is reduced in the older adult, causing a rounded or forward flexion of the posture alignment, and arthritis may cause a decrease in the range of joint motion in the ankle, hip, and knee joints.

Neuromuscular System Changes Most falls occur during dynamic balance situations, and older adults, especially those with balance impairments, may have difficulty regaining stability after a slip or trip. In order to understand the extent to which constraints on neuromuscular responses contribute to poor balance in these situations, researchers have been asking the following question: When healthy older adults are faced with an unexpected threat to standing balance, such as the sudden start or stop of a bus or a subway car on which they are standing, are they capable of responding to that threat in a manner as efficient as a young adult? In order to answer this question research has been performed to simulate these situations and to examine the characteristics of postural muscle response patterns that are activated in response to the unexpected forward or backward movement of a platform on which the subject is standing or walking (see **Figure 1**).

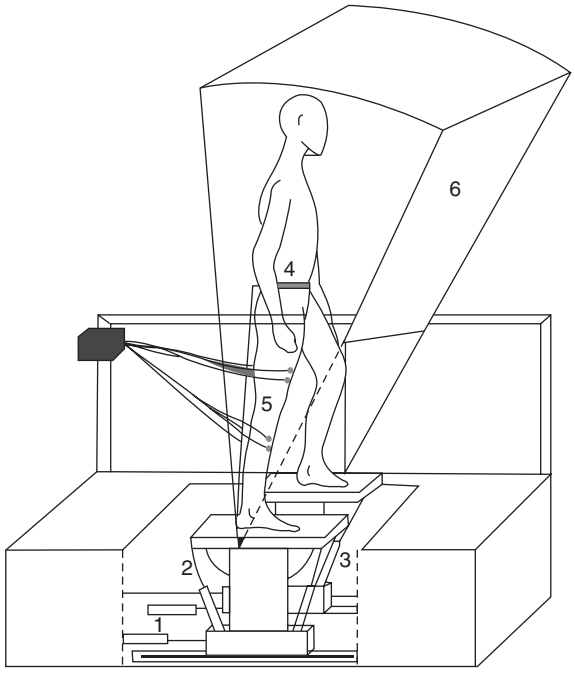

Figure 1 Experimental paradigm. Subject stands on hydraulically activated platform that moves unexpectedly forward or backward (1–3, hydraulic cylinders). A belt attached to the hips measures sway (4). Surface electrodes (5) measure muscle responses. A visual surround (6) can be rotated with the subject's sway to minimize sway-related visual inputs. (From Woollacott MH, Shumway-Cook A, and Nashner LM (1986) Aging and posture control: changes in sensory organization and muscular coordination. *International Journal of Aging and Human Development* 23: 100.)

When the balance of a young adult is disturbed by an unexpected movement of the surface on which they are standing, there is typically sway focused at the ankle joint; then muscle responses that return balance to normal are activated first in the stretched ankle muscle and radiate upward to the muscles of the thigh and hip.

Research by Woollacott and colleagues comparing the response characteristics of younger adults (mean age 25 years), healthy older adults (mean age 74 years), and balance-impaired older adults (mean age 76 years), showed that the postural muscle response organization was generally similar between the three groups, with responses being activated first in the stretched ankle muscle and radiating upward to the muscles of the thigh.

However, the groups also showed specific differences in response characteristics:

1. Onset of contraction for the postural muscles (ankle dorsiflexors) was significantly slower for both the healthy and the balance-impaired older adults compared to the younger adults when platform movements caused backward sway (**Figure 2A**); slowing of contraction onset was correlated with age (**Figure 2B**).
2. For almost half of the older adults, there was an occasional disorganization of the muscle response pattern, with proximal (thigh) muscles being activated before distal (ankle) muscles. It is interesting that this type of response organization is typical of certain patients with central nervous system lesions.
3. The older adults co-activated the antagonist and agonist muscles of a joint together significantly more frequently than the younger adults, possibly to stiffen the joints as an alternate way to increase joint stability.
4. Older and balance-impaired older adults used a higher percentage of maximum voluntary contraction amplitudes when responding to faster balance threats (**Figure 3**).
5. Older adults also tended to use a strategy of balancing that involved hip movements rather than simple ankle movements to control sway. It has been suggested that some falls in the older adult may be caused by a drop in the use of the classical ankle balance strategy and a shift toward the use of a hip balance strategy, as a result of pathological conditions such as ankle muscle weakness or peripheral sensory neuropathy.

Sensory Contributions In order to balance effectively, in a variety of environments it is necessary to utilize information from three sensory systems: the visual, somatosensory (proprioceptive, cutaneous, and joint receptors), and vestibular systems. This

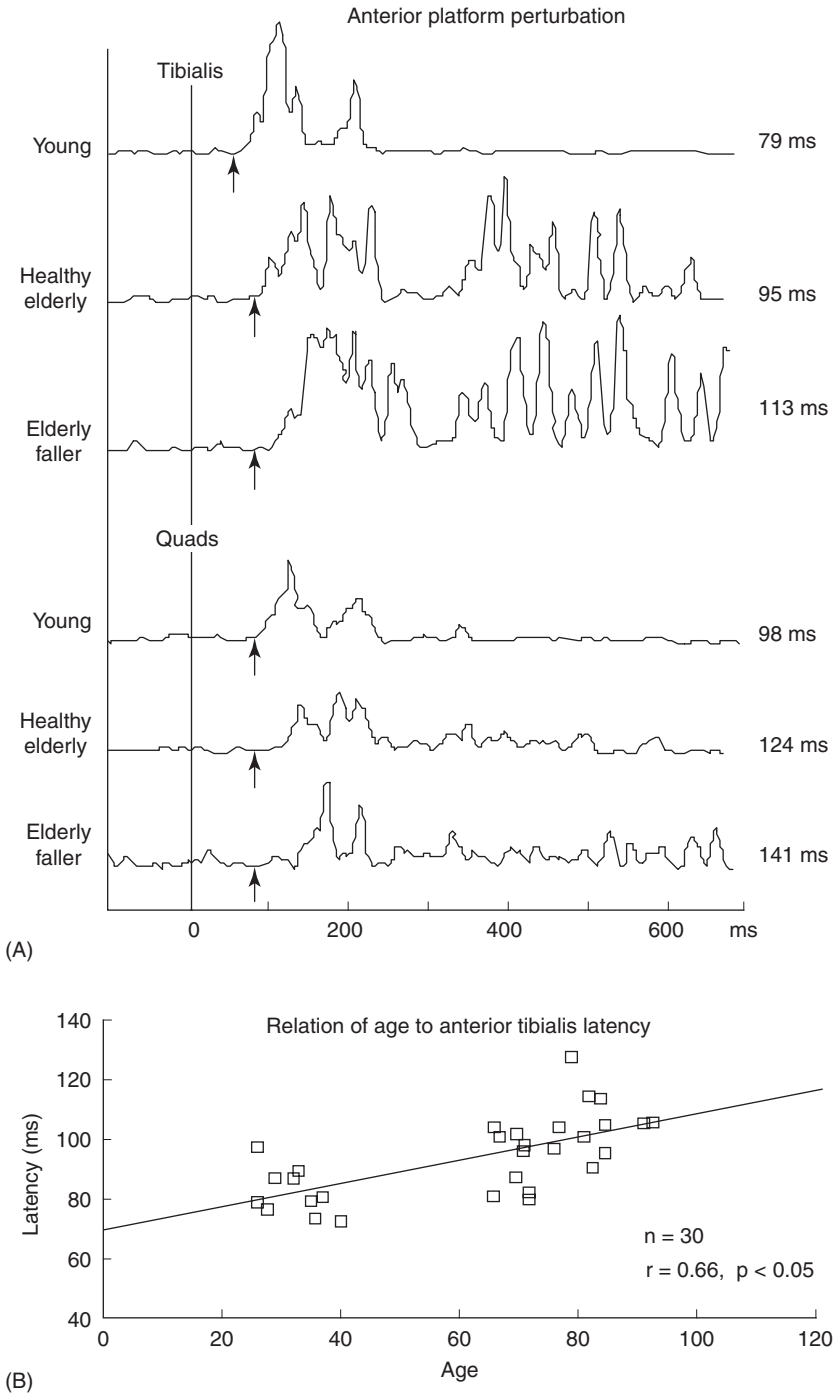

Figure 2 Changes in temporal characteristics of muscle response synergies in the healthy and balance-impaired elderly. (A) Examples of muscle responses to an anterior platform movement causing backward sway in a young adult, an older adult who was non-impaired, and an older adult with balance impairments. The onset of contraction is progressively later for the non-impaired and balance-impaired older adults. (B) The relationship between onset of contraction for the tibialis anterior muscle and age, with older adults showing slower contraction onsets. (Panel A from Shumway-Cook A and Woollacott M (2000) *Motor Control: Theory and Practical Applications*, p. 231. Lippincott Williams and Wilkins.)

information must be combined appropriately to accurately represent the body's position in space. Each sensory system contributes a different frame of reference for balance orientation. There are different sensory strategies that can be used in balance control, each involving a different weighting by the higher nervous system centers of the visual, somatosensory, and vestibular inputs. In order to remain balanced in

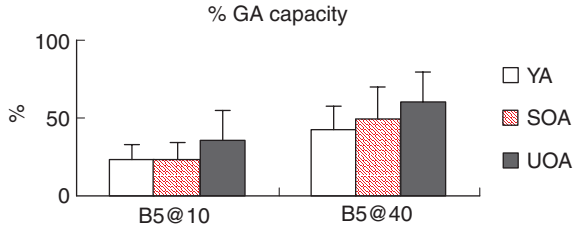

Figure 3 Graph showing the percent of maximum voluntary contraction amplitude for the gastrocnemius muscle used by young adults (YA), stable healthy older adults (SOA), and unstable balance-impaired older adults (UOA) in response to two different velocities of balance threat (5 cm at 10 cm/s and 5 cm at 40 cm/s). Balance-impaired older adults used higher levels of maximum voluntary contraction than young or healthy older adults at slow velocities (10 cm/s), while both healthy and balance-impaired older adults used a larger percentage of voluntary contraction at fast velocities (40 cm/s). (Adapted from Lin S and Woollacott M (2002) Postural muscle responses following changing balance threats in young, stable older and unstable older adults. *Journal of Motor Behavior* 34: 42.)

changing task conditions one must also be able to appropriately select the most effective sensory input for the specific task. Older adults have been shown to have deficits in specific sensory systems that could contribute to a difficulty in organizing sensory inputs appropriately for changing task conditions.

For example, studies by Whanger and Wang indicated that cutaneous vibratory sensation thresholds at the knee are increased in the frail elderly (70–90 years) compared to young adults. They noted that many of the older adults had difficulty perceiving stimulation at the ankle joint, and thus they did not include information about ankle thresholds in the study. These problems could be due to problems with peripheral neuropathy in their population.

Research on age-related changes in the visual system indicates that less light is transmitted through the retina with increasing age. Also, age-related reductions in visual contrast sensitivity cause problems in contour and depth perception, which are critical for postural control. These types of visual deterioration could result from cataracts, macular degeneration, and ischemic retinal or brain disease.

Studies by Rosenhall and Rubin on vestibular system changes in the older adult indicated that there is a 40% reduction in hair cells in the semicircular canals and the utricule and saccule, along with a similar reduction in myelinated fibers of the vestibular nerve. However, it has also been pointed out that a 75-year-old showed an almost normal number of nerve fibers in the vestibular nerve. This again points out that age-related degeneration of specific systems is not inevitable, but may be related to pathology. A partial deterioration in vestibular function can result in dizziness, which may also lead to loss of balance in the older adult. Deterioration of otolith function can lead to positional vertigo.

Older adults may not have a balance problem with deterioration in any one of these sensory systems, since the other systems contribute redundant information on balance and are usually available to compensate for this loss. However, balance problems could become apparent when walking in dimly lit areas or on unusual support surfaces such as ramps, thick carpets, or grass, because these situations have reduced sensory input redundancy. Multisensory deficits may also occur in older adults. In this case, the ability to compensate for loss of sensory information with alternative senses is difficult or impossible.

Adaptation As mentioned previously, older adults may show problems with adapting their use of sensory inputs to varying task and environmental situations. If an older adult has peripheral neuropathy and thus does not rely on somatosensory inputs, he or she may overly rely on visual inputs, even when they are inappropriate. For example, older adults may have difficulty balancing when crossing a busy intersection because visual cues from moving cars and pedestrians may create the illusion of self-sway, and the resulting postural response could cause balance loss.

How can the ability of older adults to balance under changing environmental conditions be tested? A technique called moving platform posturography allows the researcher to measure the balance of a subject under a combination of sensory conditions, including one in which the support surface rotates with the person's sway, distorting ankle joint somatosensory inputs, and another in which the visual enclosure around the subject also rotates in the anteroposterior direction with sway, again distorting visual inputs related to sway.

The labs of Woollacott, Horak, and others have examined the ability of elderly people to adapt their senses to changing conditions using posturography testing. It is of interest that there were no significant differences in amount of body sway for healthy active older adults vs. young adults except in conditions in which both ankle joint inputs and visual inputs were distorted or absent (conditions 5 and 6 as defined in the study). In these conditions, half of the older adults lost stability and needed an assistant's aid to balance. However, most of the older adults maintained stability on the second trial of these conditions, indicating the ability to adapt to changing sensory conditions with some practice.

In order to determine if the preceding types of changes in postural control with aging were indicative of normal aging or were instead due to borderline

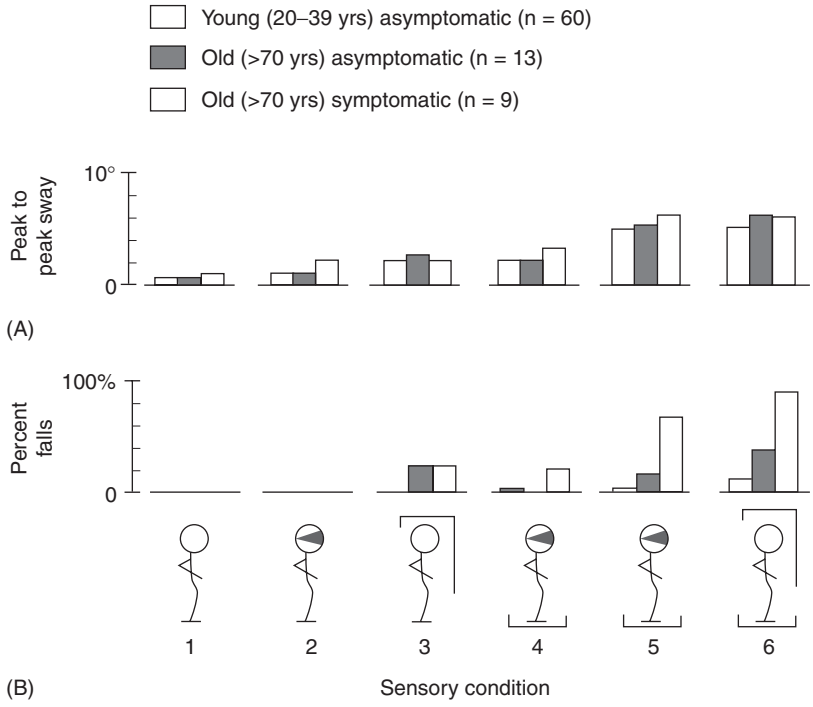

Figure 4 A comparison of the number of falls under the six sensory conditions in young non-fallers, elderly non-fallers, and elderly fallers. (From Horak F, Shupert C, and Mirka A (1989) Components of postural dyscontrol in the elderly: a review. *Neurobiology of Aging* 10: 732.)

pathology, the older adults in one of the studies (who considered themselves healthy and active) were given a neurological exam. The results of the exam were correlated with their performance on the balance tasks. Interestingly, the neurologist noted borderline neural impairment such as diminished deep tendon reflexes, mild peripheral nerve deficits, distal weakness in tibialis anterior, and gastrocnemius and abnormal nystagmus in many of the older adults. These results suggest that borderline pathology may contribute significantly to balance dysfunction in the older adult.

In a second study by Horak and colleagues, the performance of older adults with balance problems (symptomatic) was compared to that of healthy older adults (asymptomatic) and young adults (young). As shown in **Figure 4**, the older adults with balance problems showed significantly more falls with conditions 5 and 6 (both visual and ankle joint inputs were distorted or absent) than did the young and healthy older adults.

Anticipatory Postural Adjustments

Postural adjustments may be used in a reactive manner, as described previously, or in an anticipatory manner, in order to stabilize the body in advance for instability caused by a voluntary movement. One cause of falls in the older adult could be an inability to activate these anticipatory responses before voluntary movements, such as lifting a heavy object, resulting in loss of balance during the subsequent movement. Studies have shown that it is in dynamic situations such as walking, lifting, and carrying objects that a majority of falls in the older adult occur.

In the young adult, the same postural muscle response patterns that are activated during stance balance control are activated in an anticipatory manner before making a voluntary movement while standing. For example, when the adult is asked to pull on a handle, first the gastrocnemius muscle of the calf is activated, followed by the hamstrings muscle of the thigh, and then the prime mover muscle, which is the biceps muscle of the upper arm. Thus the responses are activated starting with the muscles closest to the base of support, and the response then moves upward to the proximal muscles. A research study by Inglin and Woollacott examined age-related changes in the ability of older adults to activate these postural muscle response synergies in an anticipatory manner. The study showed that older (mean age 71 years) adults showed significantly longer muscle onset latencies for postural muscles as compared to young adults (mean age 26 years) when the participants were asked to push or pull on a handle in a reaction time task. **Figure 5** shows the postural vs. voluntary muscle reaction times for each subject in the young vs. older adult group. Note that there was an increase in both

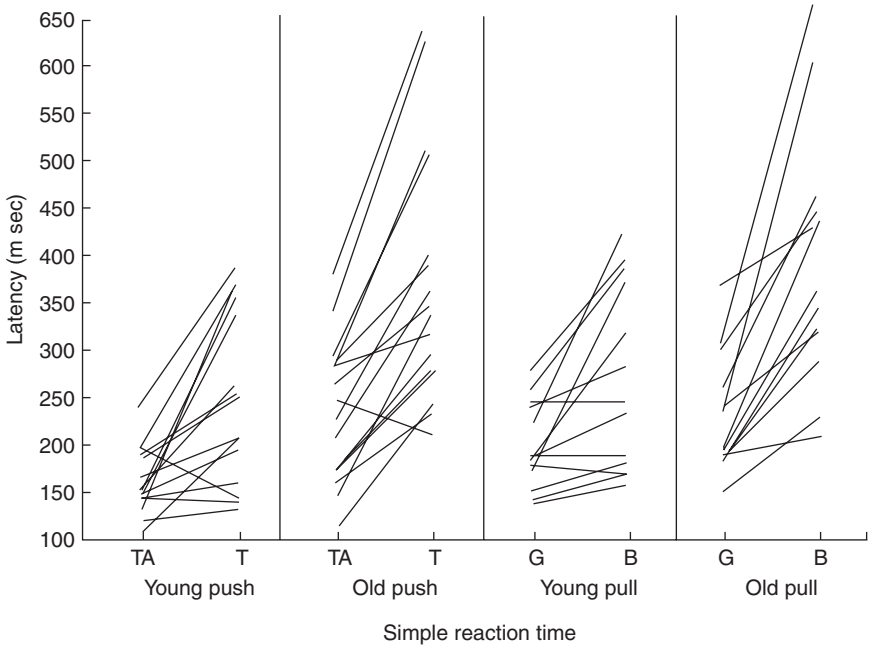

Figure 5 Individual values of postural and prime mover (voluntary) muscle onset latencies in young vs. older adults for a simple reaction-time task in which the standing subject pushed or pulled on a handle at chest height. (From Inglin B and Woollacott MH (1988) Age-related changes in anticipatory postural adjustments associated with arm movements. *Journal of Gerontology* 43: M109.)

postural muscle reaction time and the prime mover voluntary muscle reaction time. It was also noted that muscle response latencies were much more variable in the older compared to the young adults, and the organization of postural muscle responses was also significantly different. It is not clear whether these differences in postural response organization are due to nervous system deficits or to the use of an alternate strategy to compensate for other constraints within the nervous and musculoskeletal system.

A systems model of balance control would predict that this slowing in voluntary reaction time in the older adult could be caused by the need for advance stabilization by the already delayed and possibly weaker postural muscles and/or slowing in the voluntary control system itself. Since the absolute differences in onset times between the young and the older adults were larger for the voluntary muscles than for the postural muscles, there may be a slowing in both systems in the older adult.

Cognitive Systems

It is possible that, with aging, people's abilities to balance may be reduced compared to their abilities at a young age, but they may balance normally as long as they can focus attention on the task. When they have to focus on many tasks at the same time, however, they may find that their capacity to perform both the postural task and the other tasks well is reduced. For example, if an older adult is walking quickly along a busy street while carrying many packages and talking to a friend, if his or her balance is threatened, it may be more difficult to recover than if the person were walking alone in a quiet environment.

A significant amount of research from many labs (Teasdale, Redfern, Maki, and Duysens, for example) has been performed to determine the extent to which both healthy and balance-impaired older adults may have problems with balance when their attention is distracted. Shumway-Cook *et al*. showed that older adults with a history of falls swayed significantly more than young adults and healthy older adults when they were asked to perform a secondary task (a sentence completion task) compared to a control (no task condition) while standing quietly. This effect of the secondary task was increased further when older adults were asked to stand on a compliant surface, which increased postural demands. The authors suggested that healthy young and older adults could allocate attentional resources to postural control in a flexible and dynamic way, while older adults who had experienced falls had more difficulty allocating attention to postural demands.

Other studies by Brauer *et al*. showed that when balance-impaired older adults must respond to a balance threat while performing a second cognitive task, they take significantly longer to stabilize balance, as seen in **Figure 6**. This figure graphs the velocity of

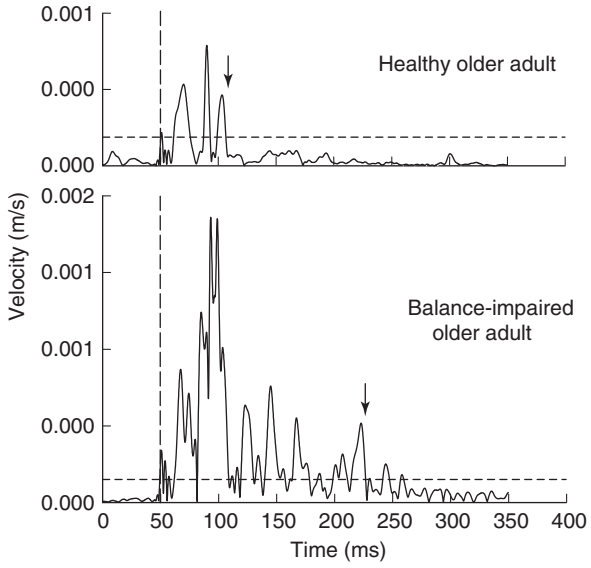

Figure 6 Graph showing the velocity of sway during recovery from a balance threat for a healthy older adult and a balance-impaired older adult when performing a second cognitive task simultaneously. Onset of platform displacement is indicated by the vertical dotted line. The time at which balance was stabilized for each person is indicated by the arrow. Note that the balance-impaired older adult required twice the time of the healthy older adult to recover balance when performing the cognitive task. (From Brauer S, Woollacott M, and Shumway-Cook A (2001) The interacting effects of cognitive demands and recovery of postural stability in balance-impaired elderly. *Journal of Gerontology* 56: M489.)

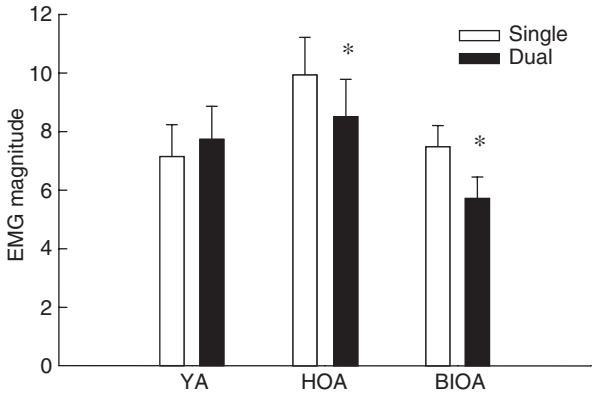

Figure 7 Graph showing the muscle response amplitudes of the gastrocnemius muscle in young adults (YA), healthy older adults (HOA), and balance-impaired older adults (BIOA) when taking a step to recover from a balance threat in a single task (balance alone) vs. a dual task (balance plus cognitive task) situation. Both healthy and balance-impaired older adults showed significantly reduced muscle response amplitudes in the dual task compared to the single task condition (noted by the asterisk). (From Brauer S, Woollacott M, and Shumway-Cook A (2002) The influence of a concurrent cognitive task on the compensatory stepping response to a perturbation in balance-impaired and healthy elders. *Gait and Posture* 15: 91.)

sway during recovery from a balance threat for a healthy and a balance-impaired older adult. The balance-impaired older adult requires almost twice the time to stabilize balance as the healthy older adult during the performance of a secondary task. In addition, when taking a step in order to recover from a balance threat, the muscle responses of both healthy and balance-impaired older adults were significantly reduced in size in the dual task compared to the single task (posture alone) condition, while those of young adults were not, as seen in **Figure 7**. This reduction in muscle response amplitude could lead to reduced step efficiency and a fall when older adults are performing a second task while recovering balance.

A second cognitive factor, fear of falling, may also affect balance performance. Maki *et al*. found that fear of falling affected balance during a spontaneous sway test and one leg stance test. The authors commented that it was not clear whether subjects with a fear of falling had a true deterioration in postural control mechanisms, or whether the fear of falling affected the balance performance in an artifactual manner.

Balance Retraining Research

The preceding research suggests that there is a significant deterioration in balance abilities in many older adults and that decreases in level of function of specific neural and/or musculoskeletal systems contribute to this deterioration. A number of laboratories are now focusing on exploring whether this deterioration in balance function can be reversed with training. Research concerning balance training has included a variety of training paradigms related to such areas as muscle strength increases, sensory balance training, and Tai Chi.

Fiatarone and colleagues studied the efficiency of muscle strength training to improve balance in frail nursing home residents. This study used high-resistance weight training of the quadriceps, hamstrings, and adductor muscle groups and found highly significant gains in muscle strength in all subjects. Changes in balance control were not measured directly, but it was noted that subjects increased walking velocity and two subjects no longer used canes to walk by the end of the training period.

A study by Hu and Woollacott used a balance training protocol that focused on improving the use of different sensory inputs and the integration of these inputs for balance control in older adults from 65 to 87 years old. Subjects were asked to balance under eight different sensory conditions in which visual and somatosensory inputs were gradually reduced or distorted. **Figure 8** shows the changes in sway of one subject under the eight conditions for the 10 days of training. Significant reductions were found in the amount of sway in the training group between the first and the last day of training in the

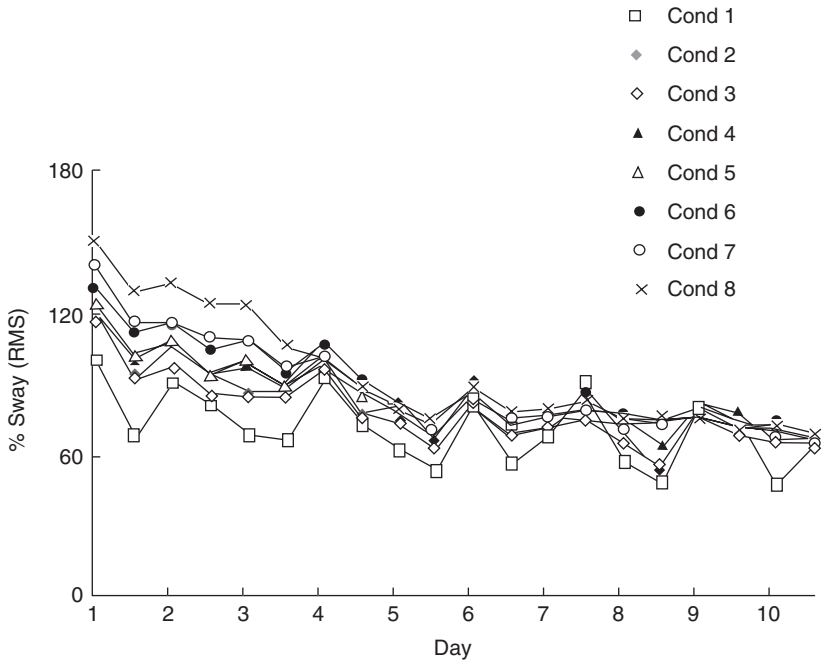

Figure 8 Percent reduction in body sway (root mean square [RMS]) under eight sensory conditions during the training period for one subject. (From Woollacott M, Moore S, and Hu M (1993) Improvements in balance in the elderly through training in sensory organization abilities. In: Stelmach GE and Homberg V (eds.) *Sensorimotor Impairments in the Elderly,* p. 384. Dordrecht: Kluwer.)

five most difficult training conditions. In addition, performance remained above control levels for at least 4 weeks after the training ended, and it transferred to a second balance task, that of standing on one leg with eyes open and closed.

In addition, increased balance abilities were accompanied by specific changes in muscle response characteristics to platform perturbations. These included significantly less co-activation of antagonist muscles after training, indicating that subjects were using more-refined balance strategies.

In a randomized controlled trial, Wolf and colleagues examined the effects of Tai Chi training vs. static balance training on balance in community-dwelling older adults. The training consisted of 1–2 sessions per week for 15 weeks. Results showed that the risk ratio for falls was reduced in the Tai Chi group but not the static balance group. In another study, Gatts and Woollacott examined the neuromuscular mechanisms contributing to improved balance as a result of intensive Tai Chi training (1.5 hours per day for 3 weeks) in balance-impaired older adults. They found that Tai Chi-trained older adults showed significantly faster postural muscle responses when recovering from a slip during walking, along with reduced co-contraction of antagonist muscle responses (compared to a control group), suggesting that their postural muscle response characteristics were more efficient after Tai Chi training.

Finally, Shumway-Cook and colleagues determined the effects of a multidimensional exercise program on balance and falls risk in 105 balance-impaired older adults (65+ years). The program consisted of muscle strength training, mobility exercises, static and dynamic balance training, and aerobic activity (walking) for 8–12 weeks (physical therapy sessions twice per week and 5–7 days of exercise at home). Results showed that participants who were fully compliant in exercise participation showed a 33% reduction in falls risk compared to the control group, which showed an 8% increase in risk across the training period.

Walking Characteristics in Older Adults

Many of the same issues that were addressed previously in relation to questions concerning the inevitability of balance deterioration in aging also apply to the research on age-related changes in gait. Earlier clinical studies on gait disorders often included patients with such problems as gait apraxia, hypokinetic-hypertonic syndrome, and marche a petit pas, and thus considered the characteristics associated with these types of pathology to be associated with the normal aging process. These disorders were often called 'senile gait.' In 1992 a careful survey by Sudarsky and Ronthal on 50 patients with previously undiagnosed gait disorders showed that a causal

diagnosis could be made in 84% of the older adults. They found that myelopathy, Parkinsonism, frontal gait disorder (normal-pressure hydrocephalus, multiple strokes), cerebellar degeneration, and sensory imbalance were typical disorders that had been previously undiagnosed. Thus, as with balance disorders, gait disorders may not be a pure age-related phenomenon.

Changes in Velocity/Stride Length

The characteristics of gait patterns can be reported in many ways. One common way to measure gait patterns is to use a stopwatch to measure walking speed. Using simple techniques such as this, it has been consistently reported that there is a decrease in walking speed with age. One of the first investigations on age-related changes in gait patterns was performed by Speilberg. He described the earliest stage of gait pattern change (between 60 and 72 years of age) as consisting of a slower walking velocity, smaller displacement amplitudes of the joints, and a shorter stride length.

Another early approach involved observations of pedestrians walking in New York City.

Walking cadence and velocity were measured using a marked distance on the sidewalk. As age increased, there was a decrease in walking velocity, step length, and step rate. These changes were similar to the first stage of change in gait in Spielberg's report. While this approach has the advantage of being performed in a setting where gait characteristics will be more natural, the disadvantages include being unable to control for difference in walking goals, such as taking a stroll vs. hurring to work, and relative health of the subjects. To overcome these limitations, laboratory studies have been performed.

Kinematic Analysis

Though information on age-related changes in walking speed and stride length is useful, it does not allow the determination of age-related changes in the movement of body segments that may cause the reductions in speed and stride length. Kinematic (video, film, or optoelectronic) analysis of gait has been used by investigators to investigate age-related changes in body motion during gait.

Murray *et al*. photographed subjects from 20 to 87 years of age while they were walking at preferred and fast speeds. Twenty kinematic measures were made from the resulting photographs. They found that, in men, gait cycle duration and stance duration increased after 65 years of age, while stride width increased after 74 years of age. They also noted that out-toeing and gait variability (rhythmicity of repeated strides) increased while peak heel elevation decreased after 80 years of age. There were also age-related changes in floor clearance patterns for the foot, decreases in knee flexion amplitude, and decreases in ankle extension amplitude at push-off. For women, similar changes were seen, except that a decreased stride length was noted after 50 years, along with a slower walking speed and faster cadence. It is interesting to note that for women, habitual use of high heels significantly influenced the gait characteristics.

Kinetic Analysis

Kinematic analysis of gait allows the description of locomotion movement patterns, but it does not give information regarding force generation by the subject. In order to determine whether there were changes in characteristics of force generation in older (62–78 years) vs. young (21–28 years) adults, Winter *et al*. compared the kinetic data of walking trials for the two groups, using an inverse dynamics model. They noted that older adults generated significantly less power by the plantar flexors at push-off and absorbed significantly less energy by the quadriceps femoris muscle during the late stance and early swing phase of gait. They suggested that a reduction in plantar flexor power during push-off could cause a shorter step length, a more flat-footed heel strike, and increased double-support stance duration, all of which have been observed consistently in other studies on gait characteristics in older adults. One cause of a weaker push-off could be a reduction in ankle plantar flexor muscle strength, which has, in fact, been noted in many other studies. In addition, high push-off power is known to act upward and forward, and is thus destabilizing. Thus it is also possible that this change is adaptive to give a more stable gait pattern.

Winter *et al*. also noted that older adults showed a trend toward reduced knee–hip covariance. Winter calculated the covariance of knee and hip from the moment-of-force characteristics between the two joints, and suggested that it can be used as an 'index of dynamic balance.' It is interesting that 10 of the older adults in Winter's study showed covariances that were similar to those of the young adults, while five of them had low covariances. Winter *et al*. suggested that the five subjects with low hip–knee covariances may have had neural or musculoskeletal dysfunction not detected on their clinical exams.

Neuromuscular Analysis

How do the previously described changes in kinetics and kinematics relate to changes in muscle response

patterns underlying gait? Finley *et al*. compared patterns of muscle activity in younger (19–38 years) and older (64–86 years) women during normal gait. They found that average electromyograph (EMG) activity levels in gastrocnemius, tibialis anterior, biceps femoris, rectus femoris, and peroneus longus muscles were higher in the older age group than in the younger group. They also noted that there were changes in muscle response characteristics at specific points in the step cycle. Thus, at heel strike, the activity of peroneus longus and gastrocnemius was elevated in the older women, compared to the younger women. The authors suggested that this elevated activity could be a result of a strategy to increase co-activation of agonist and antagonist muscles, thus increasing the stiffness of the joint and improving stability during the stance phase of gait. This strategy is often used by subjects who are not skilled in a task, or who require increased control of the task.

Studies have also examined the effects of changes in sensory systems on gait patterns in the older adult. Simoneau *et al*. examined the effect of changing the visual environment on gait characteristics during stair descent in older women (55–70 years). Stair descent was tested under the following conditions: stairs painted black, stairs painted black with the subject wearing a headband with a light-scattering plastic shield (called the blurred condition), and stairs painted black with a white stripe added at the edge of every tread. Motion analysis of the subjects' stair-climbing performance showed significantly slower cadence, larger foot clearance, and more posterior foot placement when the older adults were asked to walk under the blurred condition as compared to the other two conditions. It was also noted that foot clearance was larger than that observed previously in studies with young adults.

Changes in Adaptive Control

An important aspect of locomotor control is the ability to use visual information to change gait characteristics in order to avoid upcoming obstacles. Patla performed experiments that asked whether one contributing factor to poor walking performance in older adults might be a reduced ability to sample the visual environment during walking. In this experiment he asked both older and young adults to wear opaque liquid crystal eyeglasses with a switch that could be pressed by the subject to make the glasses transparent whenever the subject wished to sample the environment. Participants walked across a floor that either was unmarked or had regularly marked footprints on which the participants were supposed to walk. When asked to walk on the footprints, the young subjects sampled frequently and for short intervals, while the older subjects sampled less often, but for longer periods. This resulted in the older adults monitoring the terrain much more than the young adults.

Patla also performed a study in which young and older adults were asked to walk along a walkway, and when cued by a light at specific points along the walkway, to either lengthen or shorten their stride to match the position of the light. They thus tested the ability of older adults to modulate the step cycle to avoid an object. They found that the older adults had more difficulty than the younger adults in modulating their step length when the visual cue was given only one step duration ahead. They noted that young adults succeeded 80% of the time, while older adults succeeded 60% of the time when they were required to lengthen the step and only 38% of the time when required to shorten the step. However, both young and older adults performed equally well when the visual cue was given two steps in advance. Patla suggested that balance difficulties contributed to the problems that older adults had in shortening their step. This requirement of older adults to make modifications to gait patterns more than one step before meeting an obstacle may contribute to their need for increased visual monitoring of the environment during walking.

Because older adults show a decreased floor clearance for the swing leg, this could cause problems in stepping over objects, and thus result in trips. Therefore Chef *et al*. analyzed the kinematics of gait of healthy young and older adults while they stepped over obstacles of varying heights (0 inches vs. approximately 1, 2, and 6 inches). The smaller heights corresponded to typical floor and door thresholds and the larger ones to a curbstone, or a toy or pet that might be found at home. They found no age-related change in foot clearance over an obstacle. However, they noted that four of 24 older adults compared to no younger adults stepped on an obstacle during the experiment. Since the trials with obstacle contact were found equally throughout the test period, the authors predicted that inattention, rather than fatigue, was probably the cause of these incidents. They also found that older adults used a more conservative strategy while crossing the obstacles. This consisted of a slower crossing speed, shorter step length, and placement of the last heel strike before the obstacle closer to the obstacle.

The authors noted that the age-related differences in gait characteristics while crossing obstacles may be in part caused by decreased joint range of motion in the legs of the older adults. Thus age-related changes

in cognition and range of joint motion might be two factors causing changes in older adults' gait characteristics during obstacle crossing.

A second aspect of adaptive control of locomotion involves the ability to recover from a trip or slip during gait. Tang and colleagues tested the ability of young (mean age 25 years) vs. healthy older (mean age 74 years) adults to recover from an unexpected slip during gait. In this study, participants were asked to walk across a platform that unexpectedly moved forward at heel strike, simulating a slip on ice. The results showed that older adults were less stable in recovering from slips, often tripping with the swing leg, which caught on the support surface, during their recovery phase, showing trunk hyperextension in response to the slip and using a shortened stride length during recovery, as shown in the stick figure of a young vs. an older adult when recovering from a slip in **Figure 9A**. Neuromuscular response changes that contributed to this impaired recovery included a slowing of muscle contraction onset and a reduced muscle response amplitude. These delayed and weaker muscle responses thus contributed to the trips seen in the older adults during recovery. Longer-duration muscle responses were used to compensate for the slower and smaller response amplitudes, as shown in **Figure 9B**.

Factors Influencing Changes in Gait Characteristics

Though there are small but significant differences in the gait characteristics of healthy older adults compared to younger adults, studies by Heitemann *et al*. and Gehlsen and Whaley showed that older adults with a history of falls have significantly different gait characteristics than those without falls. Heitmann and colleagues noted that older women fallers were able to stand for significantly shorter times with feet in tandem position than non-fallers, and also showed increased step width during gait. These changes could be caused by undiagnosed pathology in these subjects. However it is also possible that, as a result of many falls, older adults develop a fear of falling, which also contributes to changes in gait patterns.

The results of many studies indicate that one reason older adults walk less quickly than young adults is that they consciously choose a more conservative or safe walking style. This suggests that fear of falling may contribute to changes in gait in the older adult. For example, Tinetti and colleagues found that preferred walking speed, anxiety level, and depression are significant predictors of fear of falling in older adults.

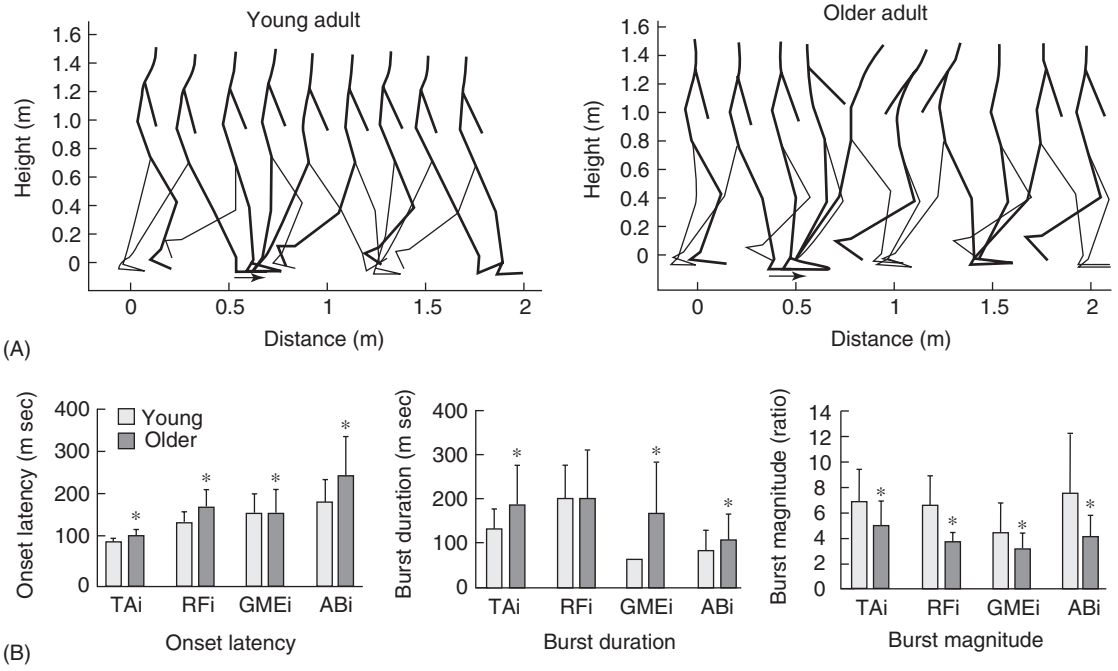

Figure 9 (A) Stick figures taken from the motion analysis of the movements of a young adult and a healthy older adult when recovering from a forward slip. The older adult shows backward extension of the trunk and the raising of the arm during balance recovery. (B) Means and standard deviations of muscle contraction onset latency, muscle burst duration, and muscle burst magnitude for the anterior muscles of the stance leg, involved in the slip. TAi, ipsilateral tibialis anterior; RFi, ipsilateral rectus femoris; GMEi, ipsilateral gluteus medius; ABi, ipsilateral abdominal muscles. (From Tang P-F and Woollacott M (1998) Inefficient postural responses to unexpected slips during walking in older adults. *Journal of Gerontology* 53: M476, M477.)

Summary

The research discussed here examined age-related changes in various neural and musculoskeletal systems contributing to balance and gait. Studies on age-related changes in balance control have shown changes in the neuromuscular response characteristics, including decreased muscle strength, a slowing of response latencies, occasional disruption in response organization, and an increased co-activation of agonist and antagonist muscles when responding to threats to balance. In addition, older adults showed more problems than young adults when balancing under conditions in which sensory inputs were reduced or absent, or when balancing when performing a second cognitive task.

Similarly, in research on gait, studies have reported a reduction in walking speed and in stride length, with an increased double support phase. This was accompanied by increases in co-activation of muscles around the ankle joint. Older adults also show less power generated by the plantarflexor muscles at push-off, which could cause the reduced stride length. The reason for the weaker push-off could be reduced muscle strength. Studies examining the effects of a variety of training programs on balance and gait characteristics have shown that muscle strength training, sensory organization training, and dynamic balance training programs, such as Tai Chi, significantly improve balance function in the elderly.

See also: Falls; Motor Control; Neuromuscular System.

Further Reading

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Behavioral Genetics

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Glossary

Additive Genetic Variance – The extent to which genotypic values add up linearly in their effect on the phenotype.

Behavioral Genetics – The study of genetic and environmental factors that create behavioral differences among individuals.

Concordance – The presence of a given trait in both members of a pair.

Genotype–Environment Correlation – The extent to which an individual's environmental experience is systematically related to their genetic predispositions.

Genotype–Environment Interaction – The extent to which the effect of a particular environment depends on someone's genetic propensity.

Heritability – A statistic that describes the proportion of phenotypic variance that is due to genetic variance, which can be partitioned into two types – additive and non-additive.

Non-additive Genetic Variance – Genetic influences due to dominance (interactions between alleles at a single locus), as well as the variance due to the higher order interactions called epistasis (interactions between alleles at different loci).

Non-shared Environment – Any environmental influence that makes family members different from

one another (including error variance; also called specific or within-family effects).

Shared Environment – Influences that contribute to phenotypic similarity among family members (also referred to as common or between-family effects).

Introduction

The age-related diseases and physiological changes that we have come to think of as part of 'normal aging' do not affect all people in the same way, nor do all individuals experience the same changes as they age. In fact, older adults are thought to be more diverse than younger adults in health, psychological functioning, and dimensions of social interaction. In other words, the observed heterogeneity among age peers increases over the life course, and the members of a cohort are said to 'fan out' as they age, becoming more dissimilar for any given characteristic. The need to explain this functional heterogeneity is a major objective of research in gerontological behavioral genetics. This article provides a brief overview of prior research on behavioral genetics, giving emphasis to the conceptualizations, empirical findings, and age focus that characterize previous studies. The next section describes research assessing genetic and environmental influences on longevity, health, cognitive functioning, personality, and psychopathology in later life. A final section reviews future research directions in the rapidly developing field of gerontological behavioral genetics.

Behavioral Genetic Studies of Aging

As of 1980, only one study specifically designed to address issues of genetic and environmental influence on biobehavioral aging had been reported: the New York State Psychiatric Study of Aging Twins, which was started in 1946 to study hereditary aspects of aging and longevity. Since that time, there has been an explosion in the number of behavioral genetic studies of aging.

American Samples

Several twin samples that focus on issues relative to gerontological research were derived from military records. The National Academy of Science-National Research Council Twin Study (NRC-NAS), started in 1955, originally consisted of almost 16 000 white male twin pairs born in the years 1917 to 1927, who were in the armed forces during World War II. Detailed assessments of lifestyle and health behaviors, medical conditions, occupation/retirement, social support, and cognitive functioning were obtained on these twins in 1965, 1983–86, and 1998–99. The current sample includes approximately 2055 pairs of twins. The National Heart, Lung, and Blood Institute Twin Study (NHLBI) represents a subsample of the original NAS-NRC twin study. The study includes 514 pairs of male twins who have participated in five in-person exams (1969–71, 1981–83, 1985–87, 1995–97, and 1999–01), with a focus on the psychological, demographic, metabolic, cardiorespiratory, anthropometric, and social aspects of proneness to coronary heart disease (CHD) and related disorders.

Other samples have been developed in specific states. The Minnesota Twin Study of Adult Development and Aging (MTSADA) is a population-based registry that includes information from 901 pairs of twins born in the state of Minnesota between 1897 and 1955 (with a majority born from 1904 to 1934). Participants were identified by birth records from the Minnesota State Health Department and were recruited using state marriage and motor vehicle records. Twins were assessed on a variety of cognitive, personality, and lifestyle measures.

The family portion of the Seattle Longitudinal Study was initiated in 1990 by selecting the adult offspring and siblings of the original sample. The sample includes 531 target parents (age range = 39–91; mean = 64), their siblings (age range = 22–89; mean = 58), and their adult children (age range = 22–74; mean = 40). All participants were community-dwelling individuals at the time of testing. Multiple measures of psychometric cognitive attributes, family environment, and personality were administered.

The Carolina African American Twin Study of Aging (CAATSA) was designed to assess genetic and environmental influences on the etiology of memory, personality, health behaviors, stress, chronic illness (e.g., cardiovascular disease, high blood pressure, arthritis), and social forces in a sample of African American twins ranging in age from 25 to 85. The registry was developed using birth records from 19 counties in North Carolina, and the current sample contains 202 monozygotic (MZ) twin pairs, 364 dizygotic (DZ) pairs, 62 siblings, and 78 singletons.

The Health of Older Twins Study (HOOTS) and the Black Elderly Twin Study (BETS) were created using national, population-based samples and were designed to estimate genetic and environmental contributions of physical frailty in older Caucasian and African American twin pairs. The sampling strategy capitalized on the use of date of birth, race, and characteristics of the Medicare health insurance claim number to identify potential pairs for study. The AARP Twin Study, on the other hand, includes volunteer sampling from the American Association of Retired Persons database.

European Registries

Much of what we know about genetic and environmental influences on the aging process comes from European registries. The Swedish Twin Registry contains information on nearly 25 000 pairs of twins born in Sweden between 1886 and 1958, with a primary focus on cancer, cardiovascular disease, depression, health and health-related behaviors, substance use and abuse, cognitive functioning, and personality. The Swedish Adoption/Twin Study of Aging (SATSA) is a subsample of the Swedish Twin Registry that includes information from 351 pairs of twins reared apart as well as a matched control group (based on age, gender, and county of birth) of 407 pairs of twins reared together. A variety of measures assessing different phenotypic traits (e.g., health, cognitive functioning, personality, social support, environmental contexts) has been obtained longitudinally at 3-year intervals from 1984 to 1993, which also include extensive in-person testing on a subsample of 150 pairs (at 3-year intervals from 1985 to 2002).

A second subset of the Swedish Twin Registry is the Octogenarian Twin Study (OCTO Twin), which is based on twins ranging in age from 80 to 89 (born prior to 1914). The twins have been assessed at 2-year intervals over an 8-year period for a total of five occasions of measurement. The sample at the first time point included 702 individuals (351 pairs; 93 MZ and 141 DZ pairs of female twins and 56 MZ and 61 DZ male twin pairs). Measures include health, personality, psychological well-being, cognitive ability, and interpersonal factors. A third subset is the Study of Dementia in Swedish Twins (HARMONY), which includes Swedish twins (65 and older) in which at least one member of the pair screened positive for dementia. Identified pairs were given an extensive evaluation that included physical and neuropsychological exams, a family history, and assessments of possible environmental factors. Association studies with candidate genes for Alzheimer's disease are also being done.

The Danish Twin Registry includes twin pairs born in Denmark between 1870 and 1910 and same-sexed twins born between 1911 and 1930 (old cohort) and 1931 to 1952 (new cohort), resulting in data from more than 32 000 twin pairs. The Longitudinal Study of Aging Danish Twins (LSADT) originated in 1995 and incorporates all registered Danish twins born prior to 1920, regardless of whether the co-twin was still living at the time the sample was created (included 3099 individuals and 733 intact pairs). The surviving members of the original cohort have been assessed at 2-year intervals since 1997. The LSADT is a cohort-sequential design, with additional cohorts added at each assessment, including twin pairs who were born in 1920–23 (in 1997), 1923–28 (in 1999), and 1929–30 (in 2001). A total of 4731 individual twins have completed an LSADT intake assessment, either through in-person interview or by proxy, including 1112 same-sex twin pairs with known zygosity. Data collection centers on aging and age-related health, metabolic and cardiovascular disease, longevity, and mortality.

The Danish Adoption Register is a study of families (e.g., adoptees, adoptive parents, biological parents, siblings) from non-familial adoptions in Denmark between 1924 and 1947. The primary focus has been on genetic and family environmental influences on psychiatric disorders (especially schizophrenia), but more recent work has also included indices of physical health (e.g., obesity, somatic disorders), health-related risk factors (e.g., smoking), and mortality and morbidity.

The old Cohort of the Finnish Twin Registry (Old Finnish Twin Cohort) includes information on 13 888 twins with a research focus on physical activity and health outcomes, including premature mortality, CHD, diabetes, hip fractures, sleep disorders, and cancers. Twins have been followed up for mortality with the National Medical Registries. In 2000, the Finnish Twin Study on Aging (FITSA) was developed to assess frailty and disability in older women. The subsample of the registry includes 217 pairs of female twins (102 MZ and 115 DZ) ranging in age from 65 to 75. The primary focus of this research is on physical capacity and functional abilities.

The Norwegian Twin Register is a population-based registry based in Oslo, Norway, that contains between 800 and 900 pairs of twins for each cohort born between 1895 and 1944. The primary focus of research using this registry is mental illness, especially manic depression, Alzheimer's disease, and schizophrenia.

The St. Thomas UK Adult Twin Registry, started in 1993, contains 10 000 pairs of twins ranging in age from 18 to 80 (average age is 45), 3000 of whom are at least 50 years of age. It is a volunteer sample, primarily female, recruited with successive media campaigns. The focus of the registry is common diseases of aging, primarily cardiovascular, metabolic (immune function), musculoskeletal (osteoporosis, arthritis, back pain), and related physical attributes (e.g., obesity). The majority of the twin pairs have participated in clinical screenings that have assessed multiple aspects of health and functioning and provided DNA samples for future work in this area (1500 of the pairs have information from a full genome scan).

The Munich GOLD Project (Genetic-Oriented Longitudinal Study of Differential Development)

includes about 250 identical and fraternal pairs of twins born between 1912 and 1932. The twins were ascertained via newspaper advertisements in Munich, Germany. The variables of primary interest are personality, intelligence, motivation, emotion, and aspects of social behavior.

The Italian Twin Registry includes a sample of 120 000 twins, with a substantive focus on aging, dementia, cardiovascular disease, diabetes, and asthma. The Twin Epidemiological Register of Rome (TERRY) includes information from 13 228 twins with data collected to assess lifestyle, development, and aging. Of these twins, 3000 pairs were born prior to 1950, and in 1997, researchers created a subregistry referred to as 'Lifestyle and Aging' (LISA), which focuses on the role of physical activity on successful aging.

Asian Registries

The Osaka University Aged Twin Registry (OUATR), formerly referred to as the Kinki University Panel, includes 12 000 pairs of oriental (primarily Japanese) twins born between 1900 and 1935, 250 pairs of which were separated early in life and reared apart. The registry reflects a volunteer sample ascertained through media advertising. The focus of the registry is on aspects of aging, including dementia, disease, changes in cognitive functioning, life satisfaction, and quality of life. A subsample has been assessed by multiple in-person cognitive tests, received comprehensive medical exams, and participated in interview assessments of lifestyle factors, family history, medical history, and diet.

The Korean Twin Registry (KTR) includes 990 pairs of twins born before 1930 and 6243 born prior to 1950. This sample is still in the developmental phases; the initial focus of the research will be health morbidity and mortality. This is a population-based registry, and to date it has only been linked with available health data from the Korean National Health Insurance. Detailed data on medical history, subjective health status, family history of disease, exercise, diet, and cancer screens are available. Cause of death, for those twins who are deceased, is also available.

Other Registries

The Australian Twin Registry was established in the late 1970s and contains more than 30 000 pairs of Australian twins. The ATR does not undertake research itself but acts as a facilitator, providing an important national and international resource for medical and scientific researchers. The old cohort of the Australian Twin Registry is composed of approximately 1200 pairs of twins ranging in age from 50 to 90 (mean = 61.4), who have been assessed multiple times since 1993 on a variety of health and lifestyle attributes.

Studies of Mid-Life

Additional studies focus on mid-life participants, with plans to follow them into old age. Adult Russian Twin Study includes data from 130 pairs of twins – 79 MZ and 51 DZ – from the metropolitan Moscow area. The mean age of the sample is 42 years (standard deviation [SD] = 8.9). Measures focus on personality, health, smoking behavior, and contextual factors that might inform on cultural and environmental influences on individual differences in health outcomes.

The German Observational Study of Adult Twins (GOSAT) is a subsample of twins from the Bielefeld Longitudinal Study of Adult Twins, which is a population-based registry in Germany. The full sample of twins consists of more than 2500 pairs ranging in age from 18 to 70 (mean = 34) recruited from all over Germany. These twins have been assessed longitudinally on measures of personality and cognitive decline. The GOSAT consists of 300 pairs of twins (162 MZ and 132 DZ), primarily females (78%), who have been assessed using peer report and observational/videotaped methods in addition to the more typically used self-reports. More specifically, data include videotapes of behavioral observations in quasi-natural settings, objective temperament assessments, unobtrusive behavior registrations, psychometric intelligence data, and measures of mental speed using elementary cognitive tasks. The primary objective is to use multiple methods to better understand genetic and environmental influences on the attributes of interest.

The Minnesota Study of Twins Reared Apart began in 1979 and has since studied more than 100 sets of reared-apart twins or triplets. Subjects participate in approximately 50 hours of medical and psychological assessments at the University of Minnesota. The majority of the twins are from the United States and Great Britain, but some reside in other countries. The sample generally includes data from 49 pairs of MZ twins (47 pairs and two sets of triplets) and 25 DZ pairs, and is predominantly females (64%) with a mean age of 40 (SD = 11.5). The members of the sample were separated very early in life (1.5 years on average) and were not reunited until adulthood (mean age of reunion = 32.6). The assessments included a large battery of cognitive tests, as well as multiple measures of personality, a medical exam, social attitudes, occupational

interests, a life history interview, assessments of the rearing environment, and a psychiatric interview.

The Mid-Atlantic Twin Registry (MATR) is a combination of the Virginia and North Carolina Twin Registries with the addition of a population-based twin sample from South Carolina. The sample includes 46 000 twin pairs, with 2250 over the age of 55. The mean age is 35, with birth years ranging from 1913 to 2000. The attributes relevant to aging include cardiovascular disease and mental health problems such as depression and anxiety.

The MIDUS (National Survey of Midlife Development in the United States) twin sample was recruited using a nationally based telephone screening survey that contacted 50 000 households for the presence of a twin. The sample includes 998 twin pairs, ranging in age from 25 to 74 (mean = 47.2; SD = 12.6), assessed on a broad battery of questionnaires in the areas of physical health, psychological well-being, and social connectedness. In addition, 216 same-sex pairs (116 MZ and 110 DZ) participated in a study of daily experiences via telephone on each of eight consecutive evenings.

The Vietnam Era Twin Registry (VET) includes information from 7375 male twin pairs, both of whom served during the Vietnam conflict (1965–75). The twins were born between 1939 and 1957, with current ages ranging from 47 to 66. The focus of the registry is on genetic epidemiological studies of physical and mental health, primarily cognitive functioning, health and disease, personality, and aspects of psychopathology. Detailed lab and clinical assessments are available on a subsample of the registry. The long-term goal is to study attributes of the aging process from middle into old age.

Genetic and Environmental Influences in Later Life

Longevity and Health

More than a century ago, Oliver Wendell Holmes suggested that "several years before birth, advertise for a couple of parents belonging to long-lived families." Because familial resemblance includes both genetic and environmental influences, however, family studies alone do not provide conclusive evidence for a genetic component to longevity. Results from twin and adoption studies are also necessary to support the conclusion that genetic factors play a role in how long people live. The most extensive work of this type comes from the Danish Twin Registry. Results from this research indicate a moderate heritability across the life span ranging from 20 to 25%, with no differences by gender. The majority of the variance is environmental in origin and is of the 'nonshared' variety, contributing to differences rather than similarities among family members.

One reason why the relationship among family members for longevity is modest is that what children inherit from their parents is not longevity per se, but rather 'frailty.' That is, children inherit susceptibility to disease, or other risk factors that contribute to their chances of death at different ages. For example, results from a Danish adoption study indicated that the early death of a biological parent corresponded to a twofold increase in mortality of the adoptee. Additionally, despite different structures in the survival data from Swedish and Danish twins, the results in both studies suggest a heritability of individual frailty of about 50%. Similar results were found in the NAS-NRC Twin Registry. In this sample, genetic differences for liability to death from disease accounted for 54% of the individual differences for this trait, indicating that significant familial resemblance for disease mortality is due to hereditary influences. Thus, estimates of the heritability of frailty have consistently been around 50%, suggesting that hereditary predispositions may influence the risk of death at different ages, rather than directly determining age at death.

Cardiovascular Disease Cardiovascular disease is a complex disorder that is determined by multiple genes, environmental factors, and their confluence. For example, the risk of death from myocardial infarction (heart attack) is one and a half to two times greater in a man whose male sibling died at an early age (less than 50 years of age). This type of premature CHD is a single gene defect, affecting lipoprotein metabolism, which accounts for about 5% of coronary disease in the population.

Because of the multidimensional nature of cardiovascular disease, attributes such as blood pressure, cholesterol levels, and glucose intolerance have been studied separately. For example, 44% of individual differences in systolic and 34% in diastolic blood pressure were genetic in origin using data from SATSA, with shared family environment accounting for up to 27% of the variance. Model-fitting analyses indicated significant age differences in heritability for serum lipid (e.g., cholesterol) and apolipoproteins. In the young cohort (age <65) the heritability estimate for total cholesterol was 63%, whereas in the older group (age >65) the heritability was 26%. Although hereditary factors are clearly important, genetic influences appear to be more pronounced at younger ages. Shared rearing environment also contributed to individual differences in total cholesterol levels (especially in the older cohort), accounting for 16 and

36% of the variance in the young and old cohort, respectively.

A report from the NHLBI focused on risk factors for cardiovascular disease in middle-aged men. The patterns of similarity for male twins suggest that the familial aggregation of cardiovascular disease results from a heritability of 60% for blood pressure (both systolic and diastolic), 25% for hematocrit, 53% for uric acid, and 56% for triglyceride levels. In addition to shared environment, genetic influences accounted for 14 to 31% (corrected for a variance difference in DZ versus MZ twins) of individual differences in cholesterol levels in these twins. In a 16-year follow-up of this sample, an inverse relationship between plasma high-density lipoprotein cholesterol (HDL-C) and the risk for the complication of arteriosclerosis was found, with a bivariate heritability of 56%. In a Japanese sample (OUATR), heritability for both types of cholesterol (low-density lipoprotein [LDL] and HDL) was 0.50.

Reports from the NAS-NRC Twin Registry demonstrated that 'healthy aging' (primarily defined as the absence of cardiovascular disease up to age 70) is under a significant degree of genetic influence, with estimates hovering around 50%. Work in this area in the early twenty-first century has begun to focus on identifying chromosomal areas that may be linked to the healthy aging phenotype.

Stroke Although multiple studies have assessed vascular disease (primarily cardiovascular), few studies have looked at the etiology of cerebrovascular accidents (CVA), more commonly referred to as strokes. Researchers, using male twins from the NAS-NRC Twin Registry, reported concordance rates of 17.7% for MZ and 3.6% for DZ twins. Although there were too few pairs of twins with strokes to reliably estimate the magnitude of heritability, these results indicate a nearly fivefold increase in the co-occurrence of stroke in MZ twins when compared to DZ twins. A long-term follow-up of twins from the Danish Twin Registry indicated that genetic factors increase the risk of stroke but that the effect is more moderate, showing a twofold increase for concordance in MZ versus DZ pairs in this sample.

Diabetes Mellitus Close relatives of patients with diabetes mellitus (DM) have increased risk of developing the disease, but the risk is almost exclusively for the same form of the disorder (insulin or non-insulin DM) as is present in the proband. Heritability appears stronger for non-insulin (type II) diabetes; concordance rates for MZ twins are 70 to 100%, whereas for insulin-dependent (type I) diabetes, the MZ concordance rates are 10 to 50%. Perhaps the strongest evidence for genetic influence on type II diabetes comes from a study on glucose intolerance; data from the NHLBI study indicated that the heritability for glucose intolerance was 88%. Others have suggested a genotype–environment interaction, speculating that environmental agents (e.g., diet) may be important in determining the severity of glucose intolerance in genetically predisposed people.

Self-Reported Health Self-reported health is of particular relevance because as a global indicator, it reliably predicts functional ability, survival, and objective measures of health status. It is also related to life satisfaction and overall cognitive functioning, and as such reflects the complex relations between physical and psychological aspects of health and illness. Research in this area has indicated that heredity is of moderate importance for perceptions of health status. For example, the heritability is 0.43 in the MTSADA, with the remaining variance due to non-shared environment. In the data from the Swedish Twin Registry, twins were divided cross-sectionally into four age groups (17–44, 45–64, 65–74, and 75–91), and results suggested that variability in self-rated health increased linearly across age groups. These age differences were also characterized by significant differences in genetic and environmental influences on the change in variability across cohorts, with the increase in variance early and late in adulthood primarily due to environmental factors and the variance in mid-life – 45 to 75 years of age – influenced by hereditary factors as well. Additionally, women generally report worse overall health, but studies do not show that this difference is genetically influenced. Similar results have emerged from Denmark and Norway. It should be noted, however, that longitudinal data are necessary to distinguish cohort differences from aging effects and to assess continuity or change in environmental influences.

Functional Status Studies have also assessed the extent to which individual differences in functional abilities (e.g., mobility, participation in leisure activities, ability to engage in light or heavy household chores, work, and travel) are affected by heredity in later life. For example, data from the NAS-NRC Twin Registry indicated that additive genetic effects accounted for 19 to 33% of the variance in functional ability in 8 of the 10 indicators assessed, but the 95% confidence intervals included 0.0 in all but three cases. Non-shared environmental effects accounted for almost all of the remaining variance. In considering the extent to which health limitations impair functional activity, the results

indicated that 21% of the variance was due to additive genetic influences and 78% to non-shared environmental effects (in this case the 95% confidence interval did not include 0.0). In female Danish twins 75 and older, heritability estimates of functional ability ranged from 34 to 47% in women 80 and older, but only 15 to 34% in women 75–79. These results suggest that interventions directed toward unique aspects of the environment (e.g., diet, nutrition, health-care utilization, stress maintenance) may be especially important in lengthening the period of active life and contributing to positive outcomes in later life.

For many aspects of health and longevity, results of behavioral genetic research indicate that similarities between parents and offspring are typically lower than resemblance between siblings within a family, suggesting that cohort or age is important to consider. It is also likely that apparent differences in heritability across the life span are due to selection effects on longevity or functional capacity. For example, genetic influences may appear to be more important for health in middle adulthood, because characteristics that are highly heritable may result in the death of one or both of the twins. The impact of the loss of these subjects from the sample (or potential sample) is an artificially lower heritability estimate for the later age groups. Gender may also be a factor; unfortunately, studies do not always converge as to whether genetic and environmental effects differ for males and females. Given that many studies, especially on adults, control for possible gender effects by statistically removing differences by gender or by including only males or females in their sample, important information may be missing regarding the role that gender plays in genetic and environmental etiologies of disease and its physiological markers.

Cognitive Functioning

Cognitive abilities are among the most heritable dimensions of behavior, with genetic factors consistently accounting for about 50% of the variability in studies of childhood, adolescence, and young adulthood. Studies of later life have indicated higher levels of heritability for general cognitive abilities (see **Table 1**) than are typically observed in younger populations. For example, assessments from the SATSA indicated that 80% of the variability for twins 60 years of age (average age) was due to genetic differences. It was originally speculated that the higher heritability estimates could be related to specific characteristics of the Swedish sample, but these results have been replicated in studies using middle-age and older subjects in United States and Norwegian samples.

Research on specific cognitive abilities (e.g., verbal, perceptual speed, spatial orientation, memory) also implicates substantial genetic involvement, albeit less than what is reported for general abilities. Across multiple studies, the heritabilities range from 0.0 to 0.86, with the lowest estimates for measures of memory and the highest estimates for verbal ability and perceptual speed. A perusal of **Table 1**, however, indicates that there is much variability in these results. It has been hypothesized that the genetic influences on the cognitive domain are more general than specific. An interesting analysis from the SATSA looked at the relationship between the factor loading of the specific scale on the principal component and estimates of heritability, and found that the factor loadings were correlated with the heritability of the tests. The authors speculated that the more a trait taps into general cognitive ability, the more heritable it is.

Interestingly, much of the remaining variance in cognitive functioning is due to non-shared environment, although there are notable exceptions here as well. For example, findings from verbal ability tests consistently illustrate the importance of environmental factors in contributing to familial similarity, with estimates for shared environment ranging from 0.14 to 0.30. The Seattle Longitudinal Study explicitly assessed the extent to which aspects of the early and current family environment (measured with the Family Environment Scale) contributed to familial similarity (between siblings and between parents and offspring) for cognitive abilities. Results indicated that early family environment, both shared and uniquely experienced, impacted familial similarity in adult cognitive functioning, especially in siblings.

Another area of later life that has received much attention is cognitive decline, and multiple studies have measured different aspects of cognitive status (e.g., the Mini-Mental Status Exam [MMSE]). One sample in which cognitive decline has been extensively studied is the NHLBI, which showed heritability estimates of 0.22 for the Iowa Screening Battery, 0.38 for the MMSE, and 0.76 for Digit Symbol. A subsample of 44 of the male twin pairs was followed over a 5-year period to assess changes in cognitive function, based on the digit symbol measure. Although the sample was small, the results indicated that digit symbol substitution was heritable (0.80 and 0.88 at times 1 and 2, respectively). The prevalence of decline (defined as one or more SD changes) was similar in both MZ (35%) and DZ (39%) twins, but the concordance rates for decline were not. For identical twins, the concordance rate

Table 1 Estimates of heritability, shared environment, and non-shared environment for a variety of cognitive abilities across studies focusing on later life[a]

Study	*Trait*	*Heritability*	*Shared environment*	*Non-shared environment*
SATSA	General intelligence	0.81	0.00	0.19
	Verbal ability	0.52–0.63	0.00–0.14	0.23–0.48
	Perceptual speed	0.51–0.64	0.00	0.36–0.49
	Spatial ability	0.40–0.58	0.00–0.11	0.30–0.60
	Memory	0.32–0.44	0.00	0.56–0.68
	Cognitive status	0.30–0.64	0.00	0.36–0.61
Norwegian Twin Register	General intelligence	0.81	0.07	0.12
	Verbal ability	0.59–0.86	0.00–0.26	0.12–0.27
	Perceptual speed	0.49–0.75	0.00–0.28	0.23–0.33
	Spatial ability	0.33–0.58	0.00–0.22	0.21–0.56
	Memory	0.51	0.10	0.39
MTSADA	General intelligence	0.80	0.00	0.20
	Verbal ability	0.56	0.30	0.14
	Performance (perceptual speed and spatial)	0.60	0.07	0.33
	Memory	0.56–0.64	0.00	0.36–0.44
Osaka/KinkiUniversity Twin Study	Spatial ability	0.60	0.00	0.40
	Memory	0.00	0.35	0.65
	Cognitive status	0.22	0.33	0.45
NAS/NRC	Cognitive status	0.30	0.18	0.52
NHLBI	Cognitive status	0.38–0.76		
LSADT	Cognitive status	0.26–0.54	0.00	0.46–0.74
Seattle Longitudinal Family Study[b]	Intellectual ability	0.29		
	Verbal ability	0.25–0.27		
	Spatial ability	0.15		
	Perceptual speed	0.07–0.27		

[a] Ranges of parameter estimates reflect multiple indices of the constructs.
[b] These are parent–offspring correlations (corrected for age at testing), which reflect familiality – 1/2 heritability and shared environment.

was 45%, whereas in fraternal twins the rate was 8%; thus, at least a portion of the rate of change in cognition (indexed by a measure of perceptual speed) is influenced by hereditary factors.

The MTSADA researchers looked at the relationship between memory and cognitive functioning, lifestyle, and personality factors. They were interested in the general observation that there are large individual differences in memory ability among older individuals. In addition, older individuals who are high in verbal ability maintain a high level of intellectual activity, have larger working memory capacity, maintain a high level of general or physical activity, and manifest little test anxiety. The researchers specifically focused on the etiology of the relationship between measures of memory capacity and measures of social class (occupation, education, and vocabulary), processing speed (reaction time, digit symbol), intellectual activity, and physical activity. The results indicated that genetic influences on memory are largely mediated by processing speed and social class, whereas environmental influences on memory are mediated to some extent by physical activity. Thus, the authors suggested that interventions for a decline in memory functioning might best be targeted at lifestyle variables such as physical activity.

Personality

Results of research in childhood, adolescence, and young adulthood indicate that genetic influence for self-reported personality is significant, but moderate, ranging from 30 to 50%. Although environmental influence is important, almost all the environmental variance is non-shared. Nonetheless, most of the variance is environmental, even for the most heritable personality traits. As is indicated in **Table 2**, heritability for personality in later adulthood is only slightly lower than results reported earlier in the life span.

Researchers have also looked at the extent to which genes and environment contribute to longitudinal stability in aspects of personality across

adulthood. In the MTSADA, genetic correlations for various aspects of the Multidimensional Personality Questionnaire across a 5-year period ranged from 0.93 to 1.0; non-shared environmental correlations ranged from 0.53 to 0.73. Similar results were found in the Finnish Twin Cohort and the SATSA. The investigators concluded that, relatively speaking, environmental influences are more important at each time point, but are less stable from time to time, whereas genetic effects are stable, but are of slightly less importance. Thus, although measures of personality are moderately heritable, the genetic effects over time appear to be consistent, contributing to continuity and not change.

One advantage of the GOSAT sample is that multiple methods of data collection are used – self-report, peer-report, and observational assessments. Their self-report data were consistent with heritability estimates from other studies of older samples (ranging from 0.42 to 0.56), whereas estimates from the peer-report (ranging from 0.57 to 0.81) and the combined self- and peer-report (ranging from 0.66 to 0.79) data were substantially higher, probably because these data allowed for measurement error to be removed from the non-shared environment category. The observational data that were collected focused on 'talkativeness,' an aspect of extraversion. Results of the questionnaire data indicated that self-reported extraversion showed a heritability of 0.56, peer-reported was 0.60, and the observational measure was 0.30. Thus, although the heritability across all types of measures was significant, the observational measure showed less heritability than the survey methods. Additional research on the impact of methodological variance is needed to fully interpret these results.

Behavioral genetic research has also assessed characteristics of personality that may be particularly relevant in later life. One example is locus of control, which has been associated with both physical health and psychological well-being. Analyses in the SATSA indicated that genetic influences are most important for self-attributions concerning responsibility and life direction, accounting for 30% of the variance. The familial similarity for the perceived role of luck in determining life's outcomes, however, is largely due to shared rearing environmental influences. Similar results were found in the OCTO Twin sample, which was used to test genetic and environmental influences on health control beliefs (i.e., due to internal control, chance, or powerful others) and the relationship with depression, life satisfaction, and indices of health in the oldest old.

A second dimension especially relevant to later life is 'type A' personality, which has been associated with cardiovascular disease. Attributes such as 'ambition,' 'hostility,' 'pressure,' and 'hard-driving,' using a structured interview, the Framingham measure, and multiple other self-report measures, indicated heritabilities accounting for 14 to 63% of the variance, with a typical heritability of 0.35. These results come from the SATSA, NHLBI, Finnish Twin Registry, Norwegian Twin Panel, and Australian Twin

Table 2 Estimates of genetic (h^2), shared environment (es^2), and non-shared environment (en^2) for measures related to the broad constructs of neuroticism (N), extraversion (E), openness to experience (O), agreeableness (A), and conscientiousness (C)

Study	*N*	*E*	*O*	*A*	*C*
SATSA					
h^2	0.31–0.39	0.24–0.45	0.40	0.12	0.29
es^2	0.04–0.12	0.00–0.13	0.06	0.21	0.11
en^2	0.55–0.60	0.52–0.72	0.54	0.67	0.60
MTSADA					
h^2	0.27–0.41	0.42–0.53	0.27	0.29	0.39–0.44
es^2	0.00–0.04	0.00–0.02	0.15	0.00	0.00–0.00
en^2	0.55–0.73	0.45–0.58	0.58	0.71	0.56–0.61
GOSAT (self-report)					
h^2	0.52	0.56	0.53	0.42	0.53
es^2	0.00	0.00	0.00	0.00	0.00
en^2	0.48	0.44	0.47	0.58	0.47
GOSAT (peer-report)					
h^2	0.61	0.60	0.81	0.57	0.71
es^2	0.00	0.00	0.00	0.00	0.00
en^2	0.39	0.40	0.19	0.43	0.29
NAS-NRC					
h^2	0.60–0.66	0.50–0.66			
es^2					
en^2					
VET Registry					
h^2				0.28–0.47	
es^2				0.00	
en^2				0.53–0.72	
Swedish Twin Registry					
h^2	0.48	0.50–0.74			
es^2					
en^2					
Old Finnish Twin Cohort					
h^2	0.27–0.31	0.32–0.36			
es^2					
en^2					
Adult Russian Twin Study					
h^2	0.49	0.49–0.59			
es^2	0.00	0.00			
en^2	0.51	0.41–0.50			
Australian Twin Registry					
h^2	0.40	0.47			
es^2	0.00	0.00			
en^2	0.60	0.53			

Registry; in fact, quite similar results were reported across a variety of samples from different cultures, utilizing different measures and analytical techniques.

Psychopathology

Dementia Dementia is a global term for any neurological disorder whose primary symptomology is the deterioration of mental functioning. Alzheimer's disease (AD) is arguably the most severe and devastating of all of the different types of dementia, accounting for about 50% of all cases of severe dementia. Many epidemiological studies have been carried out in order to identify risk factors for AD. Apart from increased age, the other variable that has been consistently identified is a family history of the disorder. For example, first-degree relatives of individuals with AD have more than double the risk of also developing AD. Twin studies, across multiple large registries, report heritabilities that range from 55 to 70%. One important use of twin studies is to try to identify environmental factors that contribute directly to the development of AD or interact with genetic effects. In a study using discordant MZ pairs from the Swedish Study of Dementia in Twins, three factors were identified that may contribute to the difference: early health, education, and experiencing a stroke. Although potential targets for intervention, these factors may be markers for more-global indices of health and environmental influence.

From a genetic perspective, AD is a complex disorder. Four different loci have been identified that relate to different forms of the disease; mutations in three of these, presenilin I (chromosome 14) and II (chromosome 1) and the amyloid precursor protein (chromosome 21), cause early-onset AD. The apolipoprotein E (APOE) gene (chromosome 19), involved in cholesterol transport in the blood, is associated with late-onset AD. The different alleles also appear to act in a dose-related fashion to increase risk and decrease age of onset, with the E4 allele being the most deleterious. A fifth site on chromosome 12 has been identified in a study of 54 families with late-onset AD. This influence on the development of AD appears independent of the APOE-4 allele and is more highly associated with the dementia with the Lewy bodies form of AD. A sixth site on chromosome 10 has also received much attention and has been replicated in several large studies. The genes at all sites related to late-onset AD contribute in some way to the formation of plaques and tangles, and involve the development or inhibition of amyloid.

Depression Depression in older adults is extremely common: perhaps as many as one-third of older adults are clinically depressed. Research is not yet sufficient to draw clear conclusions about the extent of genetic influence on depression throughout the life span; however, a meta-analysis of major depression using data from family, adoption, and twin studies estimated heritability at 37%, with the remaining variance due to unique environmental factors.

In terms of non-clinical levels of depressive affect in an older population, SATSA results suggest only modest genetic influence on self-reported depressive symptoms. There is some evidence, however, that genetic factors might increase in importance after 60 years of age, perhaps due to genetic influences on frailty or vitality. Unlike most personality measures, shared rearing environment accounted for more variance than genetic factors. Using twins from the Danish Twin Register, researchers focused on occasion-specific depression, and found that the heritability estimates ranged from 22 to 37% and were similar in males and females. If the level of depressive affect was assessed, the heritability was 69% in females and 64% in males; the researchers interpreted these findings as genetic influence on overall vulnerability to depression. The residual indicated no heritability, and the authors argued that it captured the occasion-specific circumstances that could either modify or intensify the inherited vulnerability.

Several large family studies have indicated a familial resemblance for depression. The morbidity risk for depression was about 25% for first-degree relatives of depressed probands as compared to about 10% in the population. A particularly interesting aspect of these studies concerned life events. The frequency of stressful life events was greater among the relatives of depressives than in the general population, even when negative events associated with the probands were discounted. These results suggest that both the liability for depression and the propensity to experience stressful life events are familial. Such data suggest that the relationship between life stress and depression may be more complex than was previously thought. The surprising finding that experiencing (or reporting) life events is familial is explored further in the following section.

Life Events, Social Support, and Family Environment

A new area of interest in behavioral genetics is the possibility of genetic influence on measures that are presumably measures of the environment. This line of research is based on the supposition that measures of the environment are often indirect measures of the behavior of individuals. Rather than thinking in terms of genetic influences on the environment per se, genetic influences on experiences are most

likely due to genetically influenced characteristics of individuals.

Life events is a category of environmental measures used in more than 1000 studies, with reports suggesting that life events happen (or are perceived to happen) to some people more than others. Model-fitting analyses in the SATSA demonstrated significant genetic influence on individual differences in reports of the occurrence of life events. This implies that negative life events may be genetically influenced by attributes of individuals and that events of the type traditionally reported do not just happen capriciously. To test this hypothesis, it was predicted that controllable life events, which may be related to aspects of an individual's personality or mood state, should be more heritable than uncontrollable ones. As predicted, controllable events showed greater genetic influence ($h^2 = 0.43$) than uncontrollable events ($h^2 = 0.18$) in the sample of Swedish twins. These results were confirmed in a sample of young and middle-aged adults from the Virginia Twin Registry, now part of the MATR.

Research from the SATSA and the Virginia Twin Registry has also indicated that measures of social support are heritable. This may not be surprising given that genetically influenced characteristics such as personality may affect how individuals construct their social environments and how they feel about and behave toward others. In addition, others may respond to individuals on the basis of genetically influenced characteristics. It is also possible that genetic influences are detected because most of these measures rely on self-reported perceptions of the environment, and genetic effects could accrue because these perceptions filter through a person's memories, feelings, and personality.

Multivariate genetic analyses have explored the etiology of the association between measures of social support and psychological well-being in later life. Results consistently indicate that both genetic and environmental influences are important in the etiology of this relationship. That is, the genetic influences that contribute to the perceived adequacy of the support network also contribute to depressive symptoms and life satisfaction. Non-shared environmental influences also mediate this phenotypic relationship. The process by which this occurs awaits longitudinal analyses. However, some research has suggested that genetic and environmental effects that contribute to perceptions of social support may act as a resource for psychological well-being.

Similar types of analyses have also focused on the etiology of measures of family environments. Results indicate that measures of family environment, whether retrospective to the rearing environment or involving the current family environment, show at least some genetic influence. Even more surprising, across a variety of studies, measures of warmth consistently show greater genetic influence than measures of control. Studies of this type establish a need to reformulate thinking about the environment as being something 'out there' that impinges on the organism in a unidirectional manner. One direction for future research in this area is to begin to identify those genetically influenced characteristics of individuals that are responsible for the genetic variance found in these 'environmental' measures. Likely candidates include cognitive functioning and personality traits.

Future Research Directions

Results of behavioral genetic research of the second half of the life span indicate the need to consider both genetic and environmental sources of individual differences in the aging process. Behavioral genetics provides a theory that can go beyond the simple nature–nurture comparisons to consider different types of genetic (additive and non-additive) and environmental (shared and non-shared) influences, the developmental interface between nature and nurture, and the etiology of age-to-age continuity and change.

Although most of the gerontological behavioral genetic studies described are ongoing, additional longitudinal research is needed. Results of cross-sectional studies of genetic and environmental influences on behavior have indicated that there may be some important etiological differences at various points in the life span. Additionally, the etiology of continuity and change for one trait of interest is not necessarily related to another; thus, the assessment of whether genetic influences are stable needs to be tested empirically for each phenotype of interest. It has also been suggested that gerontological research should concentrate on understanding transition periods in later life, especially those that have functional significance. In other words, research of the future may focus on the etiology of functional changes in older adults as they move from optimal functioning to normal functioning, or from normal functioning to disease states or pathological functioning. Through the use of longitudinal behavioral genetic designs (e.g., longitudinal analyses of phenotypic relationships in genetically related individuals), it is possible to disentangle the dynamic pattern of genetic and environmental influences on development in later life.

Most of what is known about the genetics of individual differences in aging comes from quantitative genetic research on twins and adoptees. Stunning advances in molecular genetics, however, will

make it increasingly possible to identify specific genes responsible for the nearly ubiquitous genetic influence seen for behavior. Many of the studies described have banked subjects' DNA for future studies, are conducting candidate gene searches, or have done entire genome scans. The allure of molecular genetics, however, should not detract from the need for more quantitative genetics research that can guide the search for genes. Such quantitative genetic research is likely to be most helpful in understanding nurture rather than nature, and especially the interface between them.

Genetic influences are likely to be significant and substantial for many dimensions of variability in later life. Understanding the etiology of differences among individuals may be critically important for improving the quality of later life. Understanding the causal factors underlying individual differences in functioning and adjustment late in the life span represents a compelling route to advancing primary prevention and intervention programs in later life. Because the health problems discussed in this article are complex, it is unlikely that a single intervention will be appropriate. Given the results of behavioral genetic research to date, it may prove fruitful to examine the ways in which combinations of genotypes and environments work. For example, research on CHD has indicated that even individuals who eat essentially the same diet show large individual differences in CHD, probably due to differences in genetic predisposition – this is referred to as a genotype–environment interaction. In fact, research has indicated that a high blood cholesterol level appears to be a prerequisite for the deleterious effect of other secondary factors, such as hypertension, diabetes, autoimmune disorders, and coagulation factor levels. Thus, if an individual is not genetically predisposed to high levels of LDL cholesterol, then the other risk factors such as smoking or high blood pressure may not be as important to the development of cardiovascular disease. Because people are so different, it is unlikely that any single intervention or prevention strategy will work for all elderly individuals. Behavioral genetic research on individual differences in aging takes an important first step in the direction of understanding the etiology of these individual differences.

See also: Cognitive-Behavioral Interventions; Environmental Gerontology; Genetics.

Further Reading

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Bereavement and Loss

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Glossary

Bereavement – Both the situation and the long-term process of adjusting to the death of someone to whom a person feels close.

Grief – The affective or emotional responses that people often experience during the early phases of the bereavement process.

Mourning – The commonly accepted or culturally patterned ways people behave and express themselves during the bereavement adjustment process.

Resiliency – The ability to bounce back or recover from stressful and difficult losses and bereavement experiences.

Introduction

Bereavement refers to both the situation and the long-term process of adjusting to the death of someone to whom a person feels close. The term also has been used in reference to losses other than death, such as the loss of a home or personal belongings due to fire or a natural disaster. It is more common, however, to use the term bereavement in situations following the death of a friend or relative, or even an animal companion. Other terms associated with the bereavement process include grief and mourning. These terms are distinguishable from bereavement in that they refer to specific aspects of the broader process. Grief is characterized by the affective or emotional responses that people often experience during the early phases of the bereavement process. These feelings frequently include disbelief, confusion, shock, numbness, sadness, and sometimes anger and guilt. Feeling abandoned, lonely, or depressed and being preoccupied with thoughts of the deceased person and the events surrounding the death are often components of grief.

Not all persons experience these feelings, and the degree of intensity varies in those who do, but it is common for bereaved persons to feel a wide range of emotions that come and go quickly and that can reappear over many months or even years. Culture plays a role in shaping how people experience and express bereavement. Most professionals use the term mourning to refer to the commonly accepted or culturally patterned ways people behave and express themselves during the adjustment process. Mourning refers to such behaviors as crying, missing work, altering daily routines, attending funerals, cremations, and burials, following standards for dress and appearance, and participating in other rituals that are influenced by the surrounding culture.

Variety of Bereavement Experiences

Throughout our lives we experience many kinds of losses that require us to make adjustments. As infants, we become temporarily separated from parents and siblings. We leave the familiar surroundings of the home to attend school. As children, we lose toys, clothes, pets, and valued belongings. We, or our friends, move away to new neighborhoods. Children lose relationships with teachers, clubs, organizations, and peers as they advance from elementary grades through high school and college. Over the life course we lose more friendships and relationships due to job relocations, deaths, and retirement. With divorce rates near 50% in the United States, millions are experiencing the loss of marital relationships, parents, and family life. Some people also will lose hair, hearing, sight, muscle tone, independence, and mobility. In short, if we are fortunate to live long lives we will experience many significant losses. Each loss has the potential of disrupting patterns of behavior, requiring adjustments, but also adding to the course of our development. Bereavement can accompany these losses, if what was lost was highly valued by the individual.

It is important to acknowledge the numerous and diverse losses that people experience, because each can contribute to a better understanding of how people manage and cope with other bereavement situations. For example, we might better understand and help older bereaved spouses if we know more about how they experienced relocation, physical, and relationship losses earlier in their lives. Similarly, we need to appreciate the uniqueness of each loss or bereavement experience. Although sadness might be a grief response common to both relocation and the death of a spouse, it is unlikely that anger or guilt would be equally present in both situations.

As stated previously, bereavement is most commonly used in reference to losses due to death. In the field of gerontology, some of the most common death-related losses are the deaths of parents, spouses, siblings, and friends. Much of the information in this article is based on spousal bereavement in later life because more gerontological research has focused on this loss. At younger ages we are most likely to experience the death of a parent, older relative, or school classmate. Some experts have described the death of a parent as the loss of our past, the death of a spouse or sibling as the loss of the present, and the death of a child as a loss of part of our future. Again, we have learned that our early and consistent experiences with death-related losses can shape our attitudes and ways of coping well into later life. For example, the young boy who is told to be strong and not to cry after his father's death might easily grow up to be the unexpressive and isolated widower in late life.

Although statistics cannot capture the full essence of the bereavement process, they are very helpful in documenting the commonality and expectedness of the experience. Government reports have indicated that over 2 million people die each year in the United States. Over 400 000 of the deaths are children and youth under the age of 25. Also, each year there are at least 800 000 new widows and widowers.

The death of a spouse is an increasingly common experience among aging adults, particularly women. The 2000 census revealed that only 1% of the population between ages 18 and 54 were widowed, but 32% of those 65 and over and 66% of those 85 and over were widowed. A gender difference becomes increasingly apparent in the later years of life. After

age 65, nearly 45% of the women but only 14% of men were widowed. In the 85+ category, 79% of women and 38% of men were widowed. These high percentages actually underestimate the number of persons who experience the death of a spouse because they do not include those who remarried.

Multidimensional Nature of Bereavement

Bereavement is an important topic because the adjustment process can impact virtually every aspect of a person's life. This multidimensional nature of bereavement means that the coping process can affect emotions, spirituality, identity, social interactions and relationships, sexuality and intimacy, work productivity, financial stability, health, and even death. Patterns of interaction in family life are radically altered when someone dies. Family meals and other daily rituals related to getting ready for work, school, or church are affected by the absence of the deceased family member. In the case of spousal bereavement the survivor often changes her or his self-concept to an 'uncoupled identity' because she or he now carries out daily life alone rather than as part of a couple. Bereaved persons may lose their appetite and motivation to remain physically active, so nutrition, exercise, and physical well-being can be essential parts of the coping process.

The multidimensional nature of bereavement is evident in the topics that professionals from different disciplines choose for special attention. Sociologists often examine bereavement's impact on family life, interactions, life satisfaction, and the role of culture and socioeconomic characteristics in shaping these bereavement outcomes. Finding differences among men and women, rich and poor, and diverse ethnic groups are common concerns for sociologists. Psychologists frequently examine the emotions of grief, attachments to the deceased, depression, morale, and identity and how previous relationships and personality of the bereaved influence their coping strategies. Social workers are likely to assess family functioning and the need for and effectiveness of specific community services. Nurses and other health professionals are often concerned about the mental and physical well-being of bereaved persons. Economists are usually interested in the financial stability of bereaved persons and families. Because many women in the United States do not have the same level of retirement and other financial benefits as men, they are much more likely to suffer economically during widowhood. Each discipline and professional group adds a unique focus to examining bereavement experiences, and, collectively, help us to better understand the many ways that bereavement can affect our lives.

Another way to appreciate the multidimensional nature of bereavement is to recognize that bereavement takes place in a context. Although there are many common reactions and feelings that most people experience during the course of bereavement, there also are many experiences that may not be widely shared. For example, some bereaved persons feel intense guilt and anger, whereas others feel relief or a sense of celebration for the life of the deceased person. Some are overwhelmed with sadness and immobilized by depression, whereas others confront the loss as a challenge and opportunity for growth. In order to understand why one person manages very well and another never seems to adjust to the loss, it is necessary to examine the multidimensional nature of the context in which bereavement occurs. Previous life experiences, personality traits, social support received from others, circumstances surrounding the death, and a person's competency in managing the many tasks of daily living are some of the many factors that comprise the context of bereavement. Health professionals and clinicians who work with bereaved persons are better able to provide assistance when they know more about the specific aspects of each individual's bereavement context. What helps one person may not be of much value to another.

Sources of Knowledge about Bereavement

Although the subject of death has received considerable thought and discussion for thousands of years, much less attention has been devoted to the subject of how death affects those who are left to grieve. Since the mid-twentieth century, however, there has been a steady increase in interest and writing about bereavement, especially since 1990. Academic disciplines, especially psychology, sociology, social work, nursing, and other behavioral and health professions, have contributed attention and knowledge to the subject through the development of theory and research. Clinicians who work directly with the bereaved have added their knowledge about ways to help those having the greatest difficulty. Religious leaders and members of various clergy have shared their experiences regarding spiritual aspects of the bereavement process. Local bookstores are now replete with numerous autobiographical reports written by bereaved persons who have had experiences that they want to share. Four sources of knowledge – theory and research, clinical reports, religious accounts, and autobiographical accounts – each make unique contributions to our understanding of bereavement. These different sources of knowledge, however, have unique advantages and limitations that need to be

recognized because they can lead to different and competing conclusions (*see* Death and Dying).

Bereaved persons frequently turn to their clergy or their religious beliefs for comfort and guidance. Most religions have a set of beliefs regarding the questions of ultimate meaning. What is the purpose of life? Does God or a supernatural being have a plan for each specific person? Is there special meaning in the death of the loved one? Because most religions offer answers to these and other questions, religiously oriented people can find predictability, structure, and meaning to help them during the upheaval of bereavement. We have learned from research, however, that religion and spirituality are only part of the bereavement context and that the long-term adjustment process involves much more than a religious code to follow. Research has not confirmed that religious beliefs and practices are universally helpful to bereaved persons, but we do know that many people turn to their spiritual views as a source of knowledge (*see* Religion and Spirituality).

Autobiographical books on grief and bereavement are abundant because bereaved persons want to know how others have managed, whether their experiences are unique or common, and how they can cope better with their loss. These personal accounts can be useful because they offer detailed descriptions of feelings, problems, and solutions that worked for the authors. Some bereaved persons, for example, might find comfort in knowing that their feelings of anger and guilt were shared by the author and might benefit by following some of the suggestions in the book. Much caution should be exercised, however, because the author's credentials are most likely in the field of journalism rather than bereavement.

Books, articles, and reports written by therapists, counselors, and other clinicians also provide valuable knowledge about bereavement. Like autobiographical accounts, clinical reports offer detailed personal descriptions of the bereavement process and usually give suggestions for helping to alleviate problems. These in-depth reports about individuals' bereavement experiences not only are interesting, but also help to organize the experiences of people, identify serious adjustment difficulties, and inform other professionals and bereaved persons of specific intervention strategies and their consequences. Knowledge that comes from clinical practice, however, must be interpreted in a way that recognizes the uniqueness of the clients or patients. Those who receive counseling or professional clinical services are likely to differ in some important ways from those who never seek help. Bereaved persons who receive these services are more likely to be experiencing the greatest difficulty in adjusting, have less social support available to them, have financial resources adequate to pay for the services, and have a tendency to rely on others for help. If we based our knowledge about bereavement solely on information from clinical clients we would not know about the experience of the majority of bereaved persons. It is equally important to know how people manage their grief on their own and to what extent they want and need help even though they do not seek professional assistance.

Research and theory have been much slower in adding to our knowledge about bereavement, but their contributions have been essential. Sigmund Freud was one of the earliest to theorize about bereavement. In the early 1900s Freud practiced and wrote extensively about psychoanalytic theory and applied it to understanding the feelings and thoughts that follow separation or loss of attachment. His work was followed by other theorists, and eventually systematic research studies were completed. Erich Lindemann also used a psychoanalytic framework to guide perhaps the first bereavement study in 1944. His study interviewed more than 100 relatives of 13 people killed in a fire at the Boston Coconut Grove night club. Research and theory related to bereavement have steadily increased since these early beginnings. We now have numerous theories and research findings that both support and challenge what we initially believed to be true about bereavement.

Knowledge that is based on theory and research has given us information on a broader range of bereaved persons. By collecting data from people who have not sought professional help, and who represent varied cultures and social classes, we have learned much more about what is common and what is unique during bereavement. Systematic research studies, using well-developed and standardized scales, longitudinal designs, representative samples of bereaved persons and non-bereaved control groups have revealed findings that are inconsistent with and challenge some of the previous views based upon the other sources of knowledge. One of the most prominent research findings is that although bereavement is a highly stressful experience and some people report 'never getting over it,' the majority of bereaved persons are very resilient. They find personal and social resources to meet their needs and manage their adjustment process. Research also has not been able to confirm that people go through specific stages, as suggested by many clinicians and some theorists. The process is much more varied and complex than the uniform course depicted in the stage theories. Also, research has documented that not all people need to equally express their emotions outwardly to others in order to avoid a buildup of problems that will come out even worse later. Many

people who appear to be in control and able to manage their early grief very well tend to be doing very well years later. In short, all four of the sources of knowledge have added to a fuller and more useful understanding of bereavement.

Course of Adjustment

Perspectives, Theories, and Models

Because the bereavement process is multidimensional, and professionals from different disciplines are educated to emphasize specific aspects of human behavior, we have numerous perspectives, theories, and models that provide divergent views about bereavement. Perspectives, theories, and models differ in their degree of specificity and complexity, but they essentially provide a framework or set of guidelines to help describe, interpret, explain, and understand behavior, in this case, grief and bereavement. They help to focus attention on specific parts of the bereavement context and provide clarity and orderliness. If the perspectives, theories, and models are adequate and relatively accurate, they can be applied to predict bereavement adjustments and guide the development of interventions to help those in greatest need. The following section briefly summarizes some of the most prominent theories about grief and bereavement.

Psychoanalytic Theories Most of the variations in psychoanalytic theory applied to bereavement emphasize the importance of recognizing the conscious and subconscious ties or attachments that the bereaved person formed with the deceased. According to this view, the bereaved person must express rather than repress all of the feelings associated with the detachment or loss. Anger, guilt, fear, and love, when expressed by the bereaved, help lead to normal instead of abnormal grief. These theories also stress the importance of early childhood relationships and separations, because these first experiences remain throughout life. When children have traumatic losses in early life they often form ambivalent relationships later, repress their anxieties, and have greater difficulty with grief and bereavement. Separation anxiety is seen as an instinctive reaction to loss, but it is essential that the bereaved person withdraws from the deceased and forms new attachments.

Sigmund Freud, Erich Lindemann, John Bowlby, Colin Murray Parkes, and Peter Marris are the most prominent contributors to psychoanalytic theory and bereavement. Although each theorist has his own unique interpretations, they have generally agreed that grief is largely an intrapsychic process that each bereaved person must cognitively resolve in order to avoid delayed, distorted, or abnormal grief. Some of the abnormal reactions include social withdrawal, hypochondriacal symptoms, psychosomatic illnesses, and hyperactivity. Normal grief is thought to be marked by distress and impaired functioning, but recovery is expected. The bereaved person usually has a period of upset, protest, and anxiety because of the separation. He or she is likely to search for the deceased in familiar settings. Despair and depression can follow because the deceased does not return. A reorganization phase occurs when the griever accepts the reality of the loss, resolves the feelings of guilt and anger, restructures his or her life, and returns to normal functioning. These theories suggest that bereavement follows a relatively ordered progression of phases and that unresolved grief occurs when the sequence is disrupted or distorted.

Stress, Appraisal, and Coping Theories Theories of stress, appraisal, and coping have been applied to bereavement because the death of a spouse, parent, child, or sibling is generally considered to be among the most stressful events that can happen. Stress exists when the demands on the individual exceed the resources readily available to meet the demands. The death of a loved one, particularly when the deceased was an important part of the daily life of the bereaved, creates stress in many ways for the survivor. Daily life is radically changed because the bereaved can no longer rely on the deceased for ongoing companionship, conversation, security, guidance, comfort, love, sharing, listening, and instrumental assistance, such as financial support, transportation, and caregiving. Bereavement requires the survivor to change and adjust to an environment in which the deceased is absent.

When bereavement occurs, each person must appraise cognitively his or her situation; this is usually done consistently with their previously established patterns of dealing with stress. Cognitive appraisal means that people consciously assess their loss, try to make sense out of it, and determine the consequences. The degree of stress and subsequent adjustment difficulties are largely dependent on the bereaved person's appraisal of the situation and the coping strategies that she or he uses.

The most common types of appraisal are pain, threat, challenge, and relief. Those who primarily see the pain of their loss often focus their attention on the damage already done and expend much of their energy in anger, sadness, and depression, and their coping strategy often involves withdrawal, self-blame, and feeling overwhelmed. Those who see their loss as a threat are aware of the stress but are

uncertain about their ability to deal with it. The death of their loved one means that they see other losses that are likely to follow. Their coping strategies usually include fear and worry about future threats to their lives. Rather than focusing their energy in broader ways to make their adjustment easier, they often engage in wishful thinking. The bereaved who see the loss as a challenge recognize the stress and the need to adapt. They assess their strengths, limitations, and needs and pursue a course of action that will allow them to learn and possibly grow from the experience. Having pride, self-confidence, motivation, and some skills in doing the many tasks of daily living helps the bereaved to define the situation as a challenge and follow a more problem-focused approach to adjustment. Richard Lazarus, Susan Folkman, Leonard Pearlin, and many others have advanced the theory and research on stress, appraisal, and coping in which their perspective continues to make very important contributions to understanding bereavement.

Stage and Task Models Ever since Elizabeth Kubler-Ross proposed the well-known stage model of the dying process, it has been applied to many discussions of how people deal with problems and life crises. According to this model, the dying person passed through a naturally occurring sequence of experiences, beginning with denial and progressing through anger, bargaining, depression, and eventually culminating in acceptance. Because bereaved persons and many professionals became familiar with the stage model developed by Kubler-Ross and they could see many similar emotions, thoughts, and issues expressed during the course of bereavement, it seemed only natural to apply the sequential and progressive stages to bereavement.

Although research has identified and confirmed that bereaved persons experience many of the same kinds of emotions, thoughts, and behaviors presented in the stage models, the overall bereavement process appears to be much less orderly, sequential, and uniform than these models suggest. For example, some bereaved persons report many years after the loss that they sometimes feel the sadness, pain, and regret that they experienced in the first several weeks. The stage models have contributed to our knowledge about bereavement, however, because they have helped to identify parts of the complex process and have provided a foundation for further study.

Similar to the stage models, and building on some of the concepts from other theories, is the idea that adaptation requires the bereaved person to accomplish or complete specific tasks. William Worden's 'tasks of mourning' approach is an example. His work is based on the assumption that grief is work, requiring both emotional and physical energy to complete. He suggests that it is important for the bereaved to eventually accept the reality of the loss, to experience the pain of grief, to adapt emotionally and socially to an environment in which the deceased is missing, and to psychologically relocate the deceased person in their life and move forward. Although many other specific tasks can be added to his model, it does provide another useful approach to be used in helping bereaved persons. The task-oriented approach highlights the importance of being active and learning new skills rather than simply being passive and allowing time to pass and heal the wounds of grief. Worden's tasks of mourning approach is further extended by another theory described next.

Dual Process Model The most recent and important theoretical development in the field is the emergence of the dual process model (DPM) of bereavement, described by Margaret Stroebe and Henk Schut. This model suggests that positive adjustments require the person to deal effectively with two types of stressors and processes and oscillate (go back and forth) between them. First, 'loss orientation' is largely focused on expressions of emotions and finding a balance between letting go and maintaining the bonds to the deceased. Restoration is the second component; it refers to the need to attend to daily life challenges, learn to do new things, create new relationships and roles, and spend time away from the emotional features of grief. In 2005, research was under way to test the DPM among those experiencing traumatic grief and to study recently widowed older adults.

Other Theories Many other theories from social, behavioral, and health sciences have been used to understand some aspects of grief and bereavement, but most of them have not been systematically tested in research. Some of the theories have received only limited attention even though they have considerable promise in explaining and predicting bereavement behaviors and helping bereaved persons through the process. For example, family and systems theories, symbolic interactionism, and the health belief model have much to add but have not been extensively used.

Family and systems theories are relevant to bereavement because bereaved people are members of nuclear and extended families and their lives take place within functioning systems. People do not live in total isolation from families, groups, and organizations, and their experiences within these units are

important parts of the broader bereavement context. An 80-year-old widow is impacted by how other family members grieve the death of her husband, who also may have been a father, grandfather, uncle, or brother. Just like individuals, families grieve. During bereavement, some family members provide strength and support to one another, and other families create more conflict and tension. Systems theory recognizes that people are parts of larger systems and that individual lives consist of various functioning parts as well. Anger and depression following bereavement can easily carry over from the home to the workplace and many other social settings, thereby impacting and further complicating other relationships. Symbolic interaction theory, which comes from the discipline of sociology, has much to offer on the topic of bereavement. The theory emphasizes the importance of social interactions with others and how they shape a person's self-concept or identity, which in turn influence behavior. Bereavement losses have the potential of altering a person's interactions and self-concepts, and ultimately bereavement adjustments. From the field of health education, the health belief model examines the way bereaved persons make decisions and what they take into account when deciding on a course of action. Bereavement can very easily lead to neglect of one's own health. This approach suggests that a broad range of factors, including messages in the media, can influence bereavement behaviors by identifying healthy behaviors to pursue and stressing the likelihood of positive outcomes that will follow. Grief requires energy, for example, so good nutrition and some regular exercise might assist with making other bereavement adjustments.

Finally, the most prominent theories in the field of gerontology are relevant to understanding bereavement, but they have not received much attention. Disengagement, activity, continuity, and age-stratification theories have contributions to make, and it is hoped that in the future they will be examined and tested in research. Disengagement theory would suggest that those who were already gradually withdrawing from society would have less difficulty during bereavement than those who have not yet begun the process of withdrawal, as the bereavement experience would not seem as abrupt to them. Activity theory would argue in favor of maintaining relatively high levels of physical activity during bereavement because that would help create greater life satisfaction and well-being. Continuity theory would suggest that the best course of action during bereavement would be for the bereaved to continue doing most of the things that she or he had always enjoyed. Age-stratification theory could be used to better understand why age might influence bereavement adjustments and that people in different age cohorts have different needs and values, differences that will create somewhat unique grief experiences. In short, theory helps to inform and guide research, and considerably more of both theory and research is needed to improve the knowledge about grief and bereavement.

Research on the Bereavement Process

Research on bereavement has increased considerably since the mid-1980s. In some studies, researchers waited many weeks and months to interview bereaved persons, and in others they obtained information only days after the death occurred. Some followed bereaved persons for several years to examine long-term outcomes, but many studies obtained information at just one point in time, providing a limited picture of the process. Only a few projects included non-bereaved control groups, even though it is valuable to be able to compare the thoughts, feelings, and behaviors of bereaved persons with those who are not experiencing death-related bereavement. Research has included more women than men, more adults than children, and more Caucasians than racial and ethnic minorities. Even with these and other limitations, research has improved the understanding of grief and bereavement. It is not possible to review all or even most of these findings, but five of the most important general conclusions are presented here.

First, bereavement is very stressful, but many people manage their losses with considerable resiliency. In the case of spousal bereavement, the majority of research participants report that their loss situation is the worst and most stressful thing that has ever happened to them. The death of a child also creates stress and is particularly difficult because children are expected to live longer than their parents. To adults, it is disturbing when both of their parents are deceased because it means that their own generation in the family is now the oldest. The death of a spouse, parent, or child almost always brings out thoughts of mortality and death among the survivors. In our culture, thoughts about the inevitability of death are usually troubling because we have not openly discussed death. Some researchers have attempted to identify how many people continue to have major difficulties that interfere with their daily lives for several years. It has been estimated that between 15 and 25% will need some kind of professional help with their bereavement adjustments.

Even though bereavement is extremely stressful, it is somewhat surprising that so many people are resilient and able to restructure their lives in ways that

allow them to find enjoyment again. Knowing this helps direct attention to those 15–25% who are most distressed and unable to manage their bereavement losses alone. This issue is discussed in greater detail in the next section, which presents information on the predictors of bereavement adjustments.

Second, there is considerable diversity among and within bereaved persons. Not all people experience the same feelings, thoughts, and actions as they move through the process. For example, a 65-year-old widow described herself in the following way 4 weeks after her husband's death: "I am a very lonely person. Lousy, all washed out, despondent, feel deserted, angry, hurt, hopeless, alone, mixed-up, cannot concentrate, very emotional, very tired, cry a lot, hateful, very bitter, misfit, nobody, very miserable, very much of a loner." This same woman described herself in much the same troubled way 2 years into the bereavement process. She added that she was concerned about herself and really hurt inside. She noted that she was sick of living alone and did not care about life. In contrast, another 69-year-old widow described herself at 6 months after her husband's death as being "independent, excited about keeping busy, enjoying the company of others, and working in my yard and doing handiwork." This diversity in bereavement reactions also is found within each individual. It is not unusual to find a person simultaneously experiencing a full range of feelings and behaviors. For example, a bereaved person can feel angry, guilty, and lonely, yet at the same time feel personal strength and pride in how he or she is coping. A 70-year-old woman described herself at length as being busy, enjoying many different activities, and doing things with other people, but her final self-descriptive comment was that she still felt lonely. It is common for bereaved persons to experience both positive and negative feelings simultaneously.

Third, a theme emerging from studies from the early twenty-first century is the recommendation to be cautious of using the terms normal and recovery to describe grief or bereavement. The same individual may experience and express herself or himself in a variety of ways during bereavement. What was once considered outside the realm of 'normal' grief may now be considered a normal part of the process. For example, talking to a deceased spouse would once have been defined as abnormal or even pathological, but more recent research findings show that this is actually a very common practice among bereaved spouses – and it is now often encouraged as a therapeutic technique.

Rather than applying rigid labels such as normal or abnormal, it is more appropriate to use terms such as common or uncommon to describe bereavement feelings and behaviors. A bereaved person is far less stigmatized from being told that she or he is experiencing some uncommon feelings than from being told "You are abnormal." Also, researchers are reporting that many bereaved persons say that they never 'get over' or recover from their grief, but they have learned 'to live with it.'

Fourth, studies have revealed that the bereavement process is more like a roller-coaster ride than an orderly progression of stages with clear time frames associated with each stage. The bereavement roller coaster is characterized by the rapidly changing emotions of grief; meeting the challenges of learning new skills; recognizing personal weaknesses and limitations; developing new patterns of behavior; experiencing fatigue, loneliness, and helplessness; and forming new friendships and relationships. Researchers have been unable to identify clear time markers associated with these many ups and downs. In fact, the highs and lows can occur within minutes, days, months, or years. Fortunately, most bereaved persons experience a roller-coaster ride that becomes more manageable over time, with fewer abrupt highs and lows. This gradual improvement may never lead to an end or resolution, however, because many bereaved spouses report: "You never get over it – you learn to live with it."

Fifth, loneliness and problems associated with managing the tasks of daily living are two of the most common and difficult adjustments for older adults. These problems are even more difficult for the spousally bereaved because their daily lives are closely connected with their spouses and they frequently become dependent on each other for conversation, love, and sharing of tasks. Loneliness is problematic because it involves missing, sadness, and a void that does not go away simply by being with or among other people. Many bereaved report feeling lonely but not being alone. In the case of experiencing the death of a parent, child, or sibling who may live many miles away, the bereaved often describe how lonely they feel when they realize they can no longer call their loved one on the phone or hear their voice again (*see* Loneliness).

Unfortunately, most older adults have not learned to do many of the tasks of daily life that are important to their health, well-being, and happiness. Many men have not learned how to prepare meals, wash clothes, and clean the house. Similarly, many older women have not learned how to do home repairs, maintain an automobile, and manage finances. Research has shown that these deficiencies further complicate the bereavement process. It is hoped that future cohorts of men and women will be better

prepared and skilled in a much broader range of tasks of daily living. Research is now under way to test the effectiveness of learning new skills as a bereavement adjustment strategy as explained in the restoration feature of the dual process model.

Predictors of Bereavement Adjustments

People often say that the passage of time will heal the wound. This statement is problematic and inaccurate because it implies that little or no effort is required to cope with the situation – simply allowing time to pass is supposed to bring about successful adjustment. Although most bereaved persons do experience less difficulty and more positive adjustments over time, it is important to recognize that it is what people do with their time that determines the outcome. Successful adjustments require active rather than passive coping strategies.

Many bereaved persons have told others that it is most helpful to take one day at a time and to remain active, busy, and socially connected with other people. Being physically and socially active during the process can help to reduce the feelings of despair, helplessness, loneliness, and being overwhelmed that often contribute to a long-term strategy of waiting – often in vain – for time to bring about healing. In addition to these active coping strategies, studies have documented the importance of having social support from others and opportunities for self-expression available, especially in the early months of bereavement. Some of the most difficult and stressful bereavement experiences occur in the first few months, when grief issues are especially intense (*see* Social Networks, Support, and Integration).

Researchers have also learned that how a person copes with loss early in the process appears to be one of the best predictors of long-term coping. Those who report having effective coping experiences in the first couple of months usually cope better than others a few years later. Bereaved persons therefore are likely to benefit most from social support that they receive early in the process and from opportunities to express how they feel at this time. Some of the most appreciated and helpful support comes from those who allow the bereaved to openly express anger, sadness, and other emotions without passing along advice and counsel. It is important for bereaved persons to know that their reactions are common and that others respect their feelings and care about their well-being. Self-help groups for the bereaved provide good opportunities for self-expression, particularly for those who do not already have someone in whom they can confide.

The importance of internal coping resources is supported by research that has focused on the role of self-esteem and self-efficacy. Both concepts represent personal coping resources that individuals develop throughout their lives. Self-esteem refers to the positive or negative judgments or evaluations that a person makes about self-worth. Self-efficacy refers to a person's ability to meet the changing demands of everyday life and feelings of confidence that he or she can do so. These two features are incorporated in the restoration component of the dual process model described earlier.

The way people feel about themselves and how skilled they are in managing the many tasks of daily living – maintaining a household, paying bills, driving a car, knowing how to access resources, and so on – will influence how effectively they adjust to the loss of a loved one. Those who develop positive self-esteem and competencies such as social, interpersonal, and instrumental skills are likely to have more favorable bereavement outcomes than those who develop negative self-images and lack self-efficacy.

Self-esteem and self-efficacy are highly interrelated because people who have confidence and pride in themselves are usually more motivated to learn new skills, and the process of becoming more competent in daily life itself creates more positive self-esteem. Bereaved persons with these positive characteristics are likely to cope quite well because they will not be content with a passive approach to coping. Conversely, bereaved who never developed these personal coping resources are likely to experience long-term difficulties because they are more inclined to believe that they deserve to remain depressed, lonely, and incapacitated. These people tend to feel overwhelmed and take few constructive actions on their own behalf (*see* Self Esteem).

The predictors of adjustment to bereavement are similar for men and women and for young and older adults; that is, age and gender are not the most influential factors in the course of bereavement. What is of greater importance is the ability of the bereaved person to develop positive feelings about her- or himself early in life, continue to enhance these views over the life course, and develop skills that help her or him to meet the changing circumstances and demands of daily living. People with these traits are more likely than others to adjust well to nearly any major life stresses or transitions. Human development is a lifelong process. In the case of late-life bereavement, the developmental process is challenged. During this transition period, the bereaved person can remain physically, psychologically, and socially disrupted or can emerge with a sense of growth from learning new skills, becoming more independent, and developing a clearer self-identity.

Interventions

Although it is tempting to conclude that most bereaved persons will need help with their adjustment process, this is not necessarily the case. Research has shown that many bereaved persons do not want or need intervention services. This point is important to recognize, because clinicians and service providers frequently assume that most older bereaved persons are depressed, socially isolated, and incapacitated by their loss. The research evidence does not support this assumption, although certainly some bereaved persons are depressed, isolated, and incapacitated. The tasks for those developing intervention services are many, and among the first should be an attempt to reach those who are at greatest risk – to seek them out rather than simply announcing the existence of the service – and encourage their participation by explaining how and why the service will be helpful. It is absolutely critical to recognize that many, perhaps most, of the potential population of bereaved persons will not want to participate. This can be discouraging to those who are committed to the value of their services, but their motivation to continue their efforts will probably be less adversely affected if they anticipate the lack of enthusiasm among many potential clients. For example, only 44% of the bereaved spouses who completed a study said that they would have liked the opportunity to attend self-help groups. In another study, only 27% of those assigned to self-help groups actually agreed to participate, and in a 2005 study, approximately 34% agreed to participate.

Interventions need to be available early in the bereavement process and continue over relatively long periods of time. There is a good deal of research evidence that the first several months (usually 1 to 4 months) are the most difficult and that early adjustments will influence outcomes much later. Also, because bereavement may last for many years and some people may not be ready for early interventions, it would be most helpful to have services available over long periods of time. This does not mean that the same people need to continue receiving services for many years, although some will have this need; rather, bereaved persons need to have an opportunity to participate when they are ready.

Because the impact of bereavement is multidimensional, it is imperative that interventions offer comprehensive and diverse services. It is unlikely that any one intervention will be capable of providing all that is needed, but each intervention should clearly identify which needs are being targeted in relation to the overall multidimensional process so that there is an awareness of what help is not being provided. For example, the death of a spouse in later life can impact emotions, psychosocial functioning, health, family life, interpersonal relationships, work, recreation, and financial situations; those designing interventions that provide primarily an opportunity for self-expression (such as self-help groups) should recognize that some dimensions are not likely to be addressed. Ideally, all communities would have available a variety of interventions or services so that each person's unique skills, resources, and circumstances could be matched to the most appropriate set of services. Although this is unlikely, we can at least strive to offer interventions with the broadest scope of impact. Therefore, whenever possible, it would be worthwhile to impact several dimensions simultaneously by providing opportunities for self-expression and the enhancement of self-esteem; by teaching new skills to complete the tasks of daily living; by enhancing and mobilizing already existing social support networks; by providing education and assistance regarding health, nutrition, and exercise; and by encouraging social participation.

Various intervention formats and professionals are needed to ensure that appropriate services are available. Not all people experience bereavement in the same way; similarly, not all people will use or benefit from the same interventions. In terms of format, some people will want to have only a one-on-one type of intervention. This might be because they are reluctant to express personal and sensitive feelings in group situations. Others have reported that they particularly enjoyed being in a self-help group because they learned from others, recognized some commonalities in their situations, and enjoyed the socializing and friendships that developed. Other new and promising formats for intervention services are those using Internet-based technology. Many organizations have created web sites offering a wide array of educational materials, and in some cases, Internet bulletin boards, chat rooms, and discussion groups. Very little research has been done to examine the effectiveness of these new formats, but they do offer opportunities to reach those who live in more remote areas, are homebound, or simply prefer to use this immediate, readily accessible technology.

Many people have skills and expertise that are well-suited for helping the bereaved. Phyllis Silverman, who developed the widow-to-widow program, has shown that widows are quite capable of assisting each other. An experienced widow can reveal to the new widow that she has been there and that she knows how it feels to grieve. Also, there are important contributions that can be made by researchers, gerontologists, psychologists, psychiatrists, physicians, social workers, nurses, occupational therapists,

art therapists, counselors, clergy, and many other professionals, including social scientists, lawyers, accountants, educators, and direct service providers. Again, because bereavement has a multidimensional impact, interventions can be developed by many different professional and trained team members. Other bereaved persons can provide a sharing of experiences while trained persons assist with legal, financial, health, spiritual, and educational issues. A multidimensional team approach is highly recommended because it will increase the likelihood of developing interventions that address the diversity of needs and lead to greater success.

It should be understood that bereavement is a common and natural experience that we all share. Unfortunately, many people are not well prepared for the pain, threats, and challenges that it presents. Because bereavement occurs in broader contexts, we do not all have the same personal and social resources available, or have the same experiences and needs. What appears to help one person may have an entirely different impact on someone else. The best way to be prepared to help bereaved persons is to be educated about the process, assess the context in which it occurs, become familiar with a wide range of helping resources, and be patient, a good listener, and non-judgmental.

See also: Death and Dying; Loneliness; Religion and Spirituality; Self Esteem; Social Networks, Support, and Integration.

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Bioenergetics

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Glossary

Basal Metabolic Rate (BMR) – Metabolic rate measured in a resting, postabsorptive individual at thermoneutrality.

Calorie Restriction (CR) – Reduction of energy intake without malnutrition by restricting dietary intake through the use of a specially formulated nutrient-dense diet. Other terms that have been used to describe this process include energy restriction and dietary restriction.

Calorimetry – A technique for determining energy expenditure by measuring heat production (direct calorimetry) or measuring oxygen consumption and/or carbon dioxide production (indirect respiration calorimetry).

Doubly Labeled Water Method – A technique used to determine production of carbon dioxide in free-living individuals by measuring differences in the rate of loss of the stable isotopes oxygen-18 (^{18}O) and deuterium (^{2}H) from individuals dosed with $^{2}H_2^{18}O$. ^{18}O equilibrates with both body water and CO_2 pools and may be excreted as either water or CO_2, while ^{2}H is entirely excreted as water.

Energy Balance – The mathematical difference between total energy intake and total energy expenditure. A positive energy balance is indicative of weight gain (energy storage), and a negative

energy balance is indicative of weight loss (energy depletion).

Free Radicals – Highly reactive molecules containing unpaired electrons that may oxidize cellular lipids, proteins, and nucleic acids.

Thermic Effect of Meals (TEM) – The energy expenditure associated with the digestion, absorption, and assimilation of food into body stores.

Total Energy Expenditure – The sum total of energy expenditure from basal metabolic rate, TEM, physical activity, and theromogenesis (i.e., energy expenditure required for maintenance of body temperature).

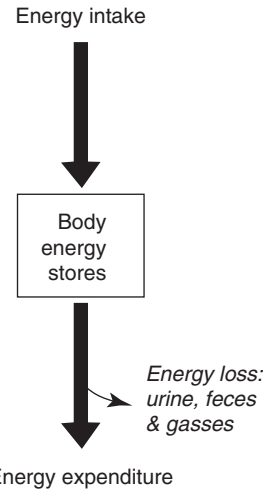

Figure 1 The energy balance equation. Aging is associated with a decrease in energy intake and energy expenditure, and at advanced age, a decrease in body energy stores.

Introduction

Bioenergetics is a broad subject covering all aspects of energy metabolism, from the biochemical and cellular level to the whole animal. The aging process is associated with changes in nearly all aspects of bioenergetics. Aging is associated with decreases in both energy intake and energy expenditure. These changes contribute to an age-related shift in body composition toward a decrease in lean body mass (LBM) and an increase in percent body fat. These age-related changes in energy metabolism place older individuals at greater risk for detrimental weight loss when faced with injury or disease. Experimental manipulations of components of energy metabolism have also been shown to have dramatic effects on life span and physiological parameters. Specifically, dietary calorie restriction is the only intervention that has consistently been shown to increase maximum life span in mammalian species, while increased energy expenditure through physical activity slows the decline in some physiological parameters with aging. Thus, bioenergetics appears to play a central role in the aging process.

Background

In animal studies, dietary calorie restriction has consistently been shown to extend life span and decrease or delay the development of physiological impairments and diseases associated with aging. This retardation of aging by calorie restriction suggests a link between energy metabolism and the fundamental mechanisms of aging. Changes in many aspects of energy metabolism are among the most consistent and noticeable characteristics of aging. These changes in energy metabolism may contribute to physical impairments and disease. Although age-related changes in the various components of bioenergetics show some differences between species, this article focuses on aging and human energetics with occasional reference to animal experiments.

Aging is often associated with shifts in energy balance, with obesity being a particular problem in midlife and wasting a problem for many who survive to advanced age. Changes in body weight (BW) and body composition are a function of total body energy balance (the difference between energy intake and energy expenditure). BW loss is accomplished by a negative energy balance. The factors in the energy balance equation, therefore, are energy intake, energy storage, and energy expenditure (**Figure 1**).

Energy intake is simply the caloric content of the food eaten by the individual. Energy consumption is a function of the total amount of diet consumed and the chemical composition of the diet. Energy intake is controlled by both psychological and physiological factors, which are discussed later in this article. Energy intake declines with advancing age.

Energy storage refers to the chemical form in which excess energy is stored in the body. Excess energy may be stored as fat, protein, or carbohydrates. The majority of the body's energy is stored either as fat (which contains the most calories per gram of tissue) in adipose tissue or as protein in muscle, with limited amounts stored as carbohydrates in the form of glycogen. Aging is associated with a decrease in LBM (muscle). During middle age, fat mass increases, while with advanced age body mass tends to decrease due to loss of both lean and fat mass.

Energy expenditure is the final component of energy balance. Energy expenditure is composed of four parts: basal metabolic rate (BMR) or resting energy expenditure, the thermic effect of meals (TEM), physical

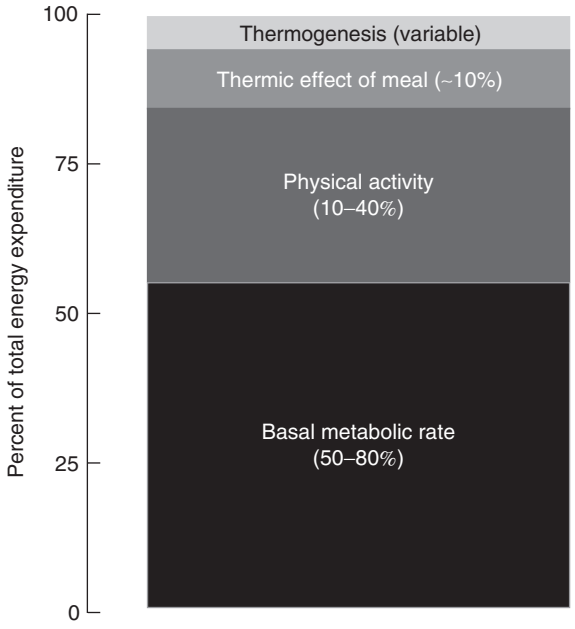

Figure 2 The components of total energy expenditure. The typical contribution of each component to total energy expenditure is indicated in parentheses. Thermogenesis represents heat production for the maintenance of normal body temperature and is typically a minor contributor to energy expenditure in the absence of significant thermal stress. All components of energy expenditure may be altered with aging.

activity, and thermogenesis (i.e., energy expenditure required for maintenance of body temperature) (**Figure 2**).

BMR is defined as the measurement of resting, postabsorptive energy expenditure in individuals at thermoneutrality; it is typically responsible for 50–80% of total energy expenditure. BMR represents the energy cost of cellular 'maintenance' processes, such as Na^+/K^+-ATPase activity, mitochondrial proton leak, protein turnover, ionic calcium movements, triacylglycerol turnover, and other substrate cycles.

TEM describes the energy expenditure associated with the digestion, absorption, and assimilation of food. TEM is responsible for approximately 10% of total energy expenditure but will vary depending on meal size and composition.

Physical activity is the most variable component of total energy expenditure and is typically responsible for 10–40% of total energy expenditure. Physical activity is the energy expenditure associated with muscular movement (beyond muscular activity that typically occurs in the resting state). Thermogenesis is the component of total energy expenditure that represents heat production for the maintenance of normal body temperature. This is typically a minor contributor to energy expenditure in individuals that are not undergoing significant thermal stress.

Aging tends to result in a decrease in all of the components of energy expenditure. Age-related decreases in BMR, physical activity, and total energy expenditure have been reported in multiple studies. The exact effect of age on TEM is not clear, with studies reporting either a decrease or no change in TEM with aging.

Energy Intake

Aging is generally associated with a decrease in energy intake, which has the potential to cause several problems. First, a decrease in energy intake is often not matched with a proportionate change in energy expenditure, which can lead to negative energy balance and loss of body mass. This can be extremely damaging to an individual already with a compromised body composition and lead to an increased risk of morbidity and mortality. Second, a decrease in energy intake is usually associated with a decreased intake of other nutrients, resulting in increased risk of malnutrition-related illnesses. Several studies have shown that a significant portion of the elderly population is deficient in at least one major nutrient. Matching energy intake to energy expenditure is clearly an important concern in the elderly.

Decreases in energy intake may be associated with several other changes that occur with the aging process. Impairment of taste and smell sensation occurs with increasing age; however, the impact of these changes on energy intake is not clear. Depression and some forms of medication are common causes of decreased appetite and food intake in the elderly. Problems with oral health, poor dentition, and gum disease also contribute to decreased food intake in some elderly people. Additionally, aging is associated with decreased saliva production and swallowing problems that can make eating difficult for some individuals.

Several studies have demonstrated that aging is associated with an impairment in the regulation of food intake that prevents appropriate compensation for periods of either under- or over-feeding. For example, young individuals typically follow a period of decreased energy intake with a compensatory increase in food intake to make up for the energy deficit, while several studies have shown that older individuals do not show this response. The mechanism for this impairment in the regulation of food intake is not entirely known. Aging has been associated with a decrease in factors that control short-term regulation of energy intake (i.e., stimuli that determine meal length). In a few studies, aging has been shown to decrease the number of opioid receptors, reduce opioid stimulation of food intake, decrease gastric fundal compliance and increase antral stretch, and slow the rate of passage through the gastrointestinal tract. Several studies have also

reported that aging is associated with increases in circulating cholecystokinin (CCK) levels and sensitivity to CCK. However, it is not clear whether these short-term signals play any role in the age-related decrease in energy intake. In experiments, total food intake is not altered by administration of short-term food intake inhibitors, presumably because the decrease in meal energy intake is compensated by increased meal frequency. Therefore, it is likely that the decreases in food intake with aging are primarily due to alterations in 'long-term' regulators of energy intake. Energy intake is controlled through a complex interaction of hormones (i.e., leptin and ghrelin) and neuropeptides located in the hypothalamus and other brain regions. While aging does not consistently increase serum leptin levels, it has been proposed that alterations in leptin sensitivity may play a role in age-related decreases in energy intake. Ghrelin levels have been reported to increase with aging, and it appears that this hormone does not play a major role in decreasing food intake with aging. In the hypothalamus, aging is associated with decreased sensitivity and/or decreased levels of neuropeptide Y (NPY). It appears that decreased NPY stimulation of feeding occurs in later life and contributes to age-related decreases in energy intake. Studies have also reported that aging is associated with a decrease in the hypothalamic levels of agouti-related peptide (AGRP) and orexin (both stimulators of food intake) and an increase in levels of cocaine-and-amfetamine-regulated transcript (CART, an inhibitor of food intake). Levels of circulating cytokines are also commonly increased in the elderly, and it is possible that they could contribute to alterations in energy intake with aging. Thus, there is evidence to indicate that neuropeptides such as NPY, AGRP, CART, and orexin may be involved in age-related decreases in food intake. Additional research to determine other 'long-term' regulators may also contribute to alterations in energy intake with aging.

It is likely that multiple factors contribute to age-related decreases in energy intake. Tremendous progress has been made in elucidating the neuroendocrine pathways responsible for controlling energy intake, and it is hoped that this work will lead to further identification of mechanisms contributing to age-related decreases in energy intake.

Body Composition and Aging

Aging is associated with very clear changes in body composition. In general, aging results in a decrease in total body mass along with a decrease in LBM and total body protein while increasing percent body fat.

Progressive loss of body protein due to a large decline in skeletal muscle mass (sarcopenia) is a well-established component of the aging process. There is evidence that muscle mass declines by up to 7% per decade between early adulthood and old age. The changes in body protein with aging are primarily a function of decreases in skeletal muscle mass, because non-muscle LBM (internal organs) often shows only slight decreases with aging. This reduction in skeletal muscle mass decreases the overall motor function of the muscles and may limit the individual's ability to respond to stresses requiring mobilization of body protein stores. Although only a slight decrease in non-muscle LBM has been reported, these changes should not be ignored and may be extremely important since the internal organs have high rates of energy expenditure. Therefore, a slight change in organ weight could have a large impact on overall energy expenditure.

The aging process results in several changes that probably contribute to the loss of muscle mass. First, aging is associated with a decrease in physical activity, reducing biomechanical forces on skeletal muscle needed for maintenance or growth of muscle mass. Exercise, especially strength training, can reverse the decline in muscle mass in the elderly. Changes in levels of anabolic hormones also contribute to the age-related decline in muscle mass. Spontaneous and stimulated growth hormone (GH) secretions are decreased with age. Similarly, circulating levels of insulin-like growth factor-1 (IGF-1) and insulin-like growth factor binding protein-3 (IGFBP-3) also decrease with age. Deficiencies in GH and IGF-1 are both associated with reduced protein synthesis and loss of LBM. Decreases in testosterone and estrogen levels probably also play a role in the depletion of LBM. Insulin-mediated suppression of body protein breakdown, unlike other actions of insulin, does not appear to decrease with age. Overall, a decrease in physical activity and decreased levels of anabolic hormones appear to be the likely causes of loss of LBM with aging.

Changes in body protein content are accompanied by an increase in percent body fat in elderly individuals. During middle age, a doubling of total body fat can occur, and development of obesity becomes a major problem. After 65–70 years of age, however, there is frequently a decrease in body weight that is the result of decreases in both lean and fat mass. However, the decrease in lean mass typically occurs at a greater rate, resulting in an increase in percent body fat and potentially the development of sarcopenia-related obesity.

Several factors contribute to increases in percent body fat in the elderly. First, a decrease in physical

activity during middle age may result in a positive energy balance and increased storage of energy in adipose tissue instead of increasing muscle mass. Second, aging is associated with a decrease in catecholamine activity and hormone-induced lipolysis in adipocytes. In women, fat accumulation also appears to be associated with hormonal changes with menopause, since estrogen and progesterone treatment tend to prevent increases in abdominal fat accumulation. Overall, aging is associated with the inability to match energy intake with energy expenditure. Decreases in energy expenditure and adipocyte lipolysis together appear to be major contributors to possible age-related increases in body fat.

Energy Expenditure

Previous attempts to determine the effect of aging on energy expenditure have been criticized for their failure to screen for 'healthy' individuals or for their reliance on cross-sectional analysis. It has been argued that many reported age-related changes in energy metabolism may reflect disease or illness rather than aging. While disease or illness can certainly alter energy expenditure, work in 'healthy' individuals has confirmed that aging is associated with a decrease in energy expenditure. Decreases in BMR, TEM, and physical activity may all be important contributors to the overall etiology of aging.

BMR is a function of the energy requirements of each of the internal organs and tissues. Research has indicated that internal organs are responsible for approximately 60% of resting energy expenditure. Skeletal muscle accounts for 35–40% of resting energy expenditure, with adipose tissue typically accounting for less than 5% of resting energy expenditure. These values show that the internal organs and skeletal muscle are responsible for approximately 95% of BMR. A change in either organ or skeletal muscle weight can, therefore, have a substantial influence on BMR. Aging is associated with a substantial decrease in skeletal muscle mass, a slight decrease in organ mass, and a decrease in BMR.

An age-related decline in BMR is a characteristic of aging that has been demonstrated in healthy and physically active individuals, although exercise can blunt the decrease in BMR. BMR decreases between approximately 13 and 20% as individuals age from their 30s to their 80s. This change in BMR appears to be non-linear, with accelerated decreases occurring at approximately 40 to 50 years of age. Gender influences both the onset of accelerated decreases in resting energy expenditure and the magnitude of these decreases. The decline in BMR begins at approximately 40 years of age in men but does not begin until after menopause, or approximately 50 years of age, in women. The magnitude of the decrease in BMR with aging also tends to be greater in men than women.

The primary reason for a decrease in BMR in both genders is the decrease in LBM. A decrease in skeletal muscle mass (sarcopenia) is the primary factor responsible for a decrease in BMR with aging. However, a few studies have shown that decreases in BMR with age parallel a reduction in organ mass, and the slight reductions in organ mass that occur with aging likely contribute to a decline in BMR. While decreases in skeletal muscle and organ mass are major contributors to age-related decreases in BMR, it appears that other processes are also involved.

Many of the cellular processes that are involved in resting oxygen consumption have the potential to contribute to age-related decreases in BMR. Protein turnover, Na^+/K^+-ATPase activity, and mitochondrial proton leak are the primary cellular processes contributing to BMR, and together account for as much as 70% of BMR. It is reported that protein turnover decreases at a rate of approximately 5% per decade, and several studies have demonstrated a decrease in protein turnover with aging. A few research groups have also shown that Na^+/K^+-ATPase activity decreases with age. Few studies have investigated the affect of age on mitochondrial proton leak, and it is not yet clear how this process is altered with aging. These results suggest that decreases in cellular energy-expending process may also contribute to age-related declines in BMR.

Mitochondria are the primary sites of cellular ATP production, and therefore many studies have attempted to determine if mitochondrial defects could contribute to age-related alterations in energy metabolism. Studies have reported that aging is associated with decreases in mitochondrial membrane potential, volume density, respiration capacity, and complex I, complex IV, adenine nucleotide translocase, and acyl carnitine transferase activities. Oxidative damage to mitochondrial DNA, proteins, and lipids also increases with aging and may provide a mechanism for the mitochondrial dysfunction. However, some have argued that aging is not associated with impaired mitochondrial function, and that some reports of age-related mitochondrial dysfunction may be the result of methodological problems. Work using a mix of *in vivo*, cell culture, and isolated mitochondria measurements is needed to determine the exact effects of aging on mitochondrial energy metabolism. However, it is likely that some level of mitochondrial dysfunction occurs with aging, and this would contribute to age-related alterations in energy expenditure.

The effect of aging on TEM is not entirely clear, with studies reporting either a decrease or no change

in TEM with aging. Diet composition, meal size, and activity all contribute to age-associated differences in TEM. Habitual exercise has been shown to increase TEM and may lessen age-related declines in this energy expenditure component. It has been suggested that decreased activity in the elderly may primarily explain their decrease in TEM. It has also been proposed that decreased intake in elderly individuals contributes to low TEM with age because TEM changes proportionately with meal size. Meal composition also appears to influence TEM, since age-related decreases in TEM have been reported to be greatest when elderly people were consuming a high-glucose meal. Problems with glucose metabolism and insulin resistance may explain the differences in TEM between the different types of diets.

Cross-sectional and longitudinal studies have shown a decrease in physical activity with aging, and this decrease in activity is not entirely explained by disease or illness. Low physical activity is a major contributor to decreased total energy expenditure with aging. Studies have shown that total hours of activity and intensity of activity decrease with aging. An age-related decrease in physical activity can contribute to reductions in total energy expenditure either directly or indirectly by altering BMR. Studies in elderly subjects have indicated that both resistance and aerobic exercise may increase BMR, and oppose age-related decreases in this energy expenditure component.

Calorie Restriction and Exercise

Calorie restriction (CR), without malnutrition, is the only intervention that has consistently been shown to increase both mean and maximum life spans in laboratory rodents. CR affects a wide range of physiological parameters (**Figure 3**) and, therefore, must alter a fundamental mechanism(s) of aging and retard the aging process. CR has been shown to delay the onset of diabetes, cancer, nephropathy, cataracts, and other age-related diseases. This broad action of CR, however, has made it difficult to pinpoint the mechanism(s) through which CR exerts its action. It is clear, however, that overall energy restriction rather than restriction of a specific macronutrient is responsible for retardation of aging with CR. Experiments using low-protein or low-fat diets without CR have failed to produce the dramatic life-prolonging results observed with CR.

It has been proposed that a reduction in body fat may be a mechanism for the actions of CR. CR results in a decrease in body fat, but the failure of experiments to show a strong correlation between body fat and length of life suggests that decreasing body fat is not the primary mechanism of CR.

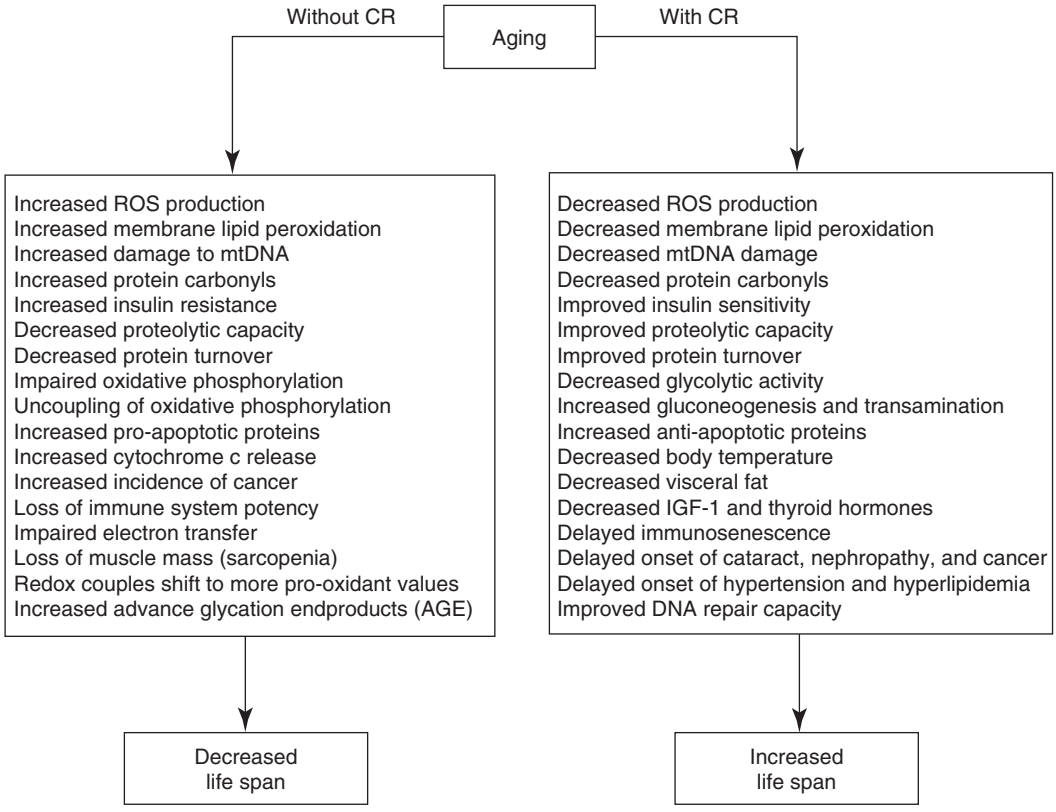

Figure 3 Physiological parameters altered by calorie restriction (CR).

CR has also been proposed to retard aging by altering the levels of hormones that regulate metabolism or mitosis. Studies in nematodes and transgenic mice have indicated that alterations in insulin and/or IGF-1 signaling are associated with increased life span. Similarly, CR has been shown to decrease circulating levels of insulin and IGF-1. Additional research is needed, however, to determine whether CR-related alterations in insulin, IGF-1, thyroid hormones, leptin, or other hormones play a central role in the retardation of aging with CR.

Another proposed theory suggests that energy expenditure and oxygen consumption are important determinates of aging. In support of this idea, long-lived animals do tend to have lower rates of energy expenditure per unit of body mass than short-lived animals. CR experiments, however, have produced mixed results, with studies reporting either a decrease or no change in mass-adjusted energy expenditure with CR. Studies investigating organ and cellular energy expenditure are needed to truly determine whether CR alters energy expenditure per unit of body mass.

The free radical theory is among the most popular theories to explain aging, and it has been proposed that CR may extend life span by decreasing cellular oxidative stress. The free radical theory proposes that aging is the result of accumulated oxidative damage produced by reactive oxygen species (ROS) generated as by-products of mitochondrial energy metabolism. Mitochondria are the principal cellular sites of ROS formation, with approximately 0.2–2% of respired oxygen converted to superoxide radicals at the mitochondria. The mitochondrial electron transport chain is the main source of ROS, with complexes I and III being the sites of ROS generation. CR has been shown to decrease oxidative damage to mitochondrial DNA, proteins, and lipids. CR also decreases mitochondrial ROS production; however, CR has not consistently been shown to alter cellular antioxidant enzymes. These results indicate that a CR-related decrease in ROS production may play an important role in the mechanism of life span extension with CR.

While CR has been shown to increase life span in a variety of animal species, it remains to be determined if it alters life span in humans. Studies in rhesus monkeys and humans do indicate that CR increases insulin sensitivity, decreases blood pressure, and reduces markers of inflammation. Long-term CR studies are under way in rhesus monkeys and humans, and the results of these studies will determine whether CR can increase life span in primate species. Physical activity is another intervention that has the potential to slow age-related changes in energy metabolism. In contrast to CR, studies in rats have shown that physical activity increases median but not maximum life span. Therefore, routine exercise may oppose age-related changes in some physiological parameters but not alter fundamental mechanisms that control longevity. Several studies have shown that routine exercise may increase total energy expenditure, BMR, and TEM. Studies in elderly individuals have shown that BMR is higher in physically active than in sedentary individuals. Physical activity, especially resistance training, may increase BMR by increasing LBM. However, aerobic exercise has also been shown, at least in some studies, to increase BMR by mechanisms independent from increases in LBM. Exercise has been shown to increase food intake and TEM, reversing typical age-related changes. Exercise programs that zincrease total physical activity would also result in increased total energy expenditure. In addition to slowing age-related decreases in energy expenditure, exercise programs have the potential to slow body composition changes with aging along with improving insulin sensitivity and reducing blood pressure. Further research, however, is needed to determine the effect of long-term exercise programs and exercise in conjunction with moderate CR, on the length of life.

Conclusions

Aging is associated with changes in nearly all aspects of bioenergetics. Energy intake is decreased with aging. Aging is also associated with a decrease in total energy expenditure, BMR, physical activity, and possibly TEM. The magnitude of these changes in energy intake and energy expenditure is generally not proportional, with weight gain and obesity occurring at middle age and weight loss becoming prevalent at advanced age. Inability to match energy intake with energy expenditure places older individuals at greater risk for detrimental weight loss associated with injury or illness.

CR and physical activity are two interventions that oppose some physiological changes with aging. CR is the only intervention that has consistently been shown to retard aging in mammalian species. Studies investigating CR have the potential to identify the mechanism(s) responsible for aging. Physical activity has the potential to slow age-related decreases in LBM and energy expenditure, and thus regular exercise programs may improve quality of life by negating these age-related changes.

See also: Diet and Nutrition; Exercise and Physical Activity; Metabolism: Carbohydrate, Lipid, and Protein; Mitochondria and Aging; Slowing of Aging.

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Body: Composition, Weight, Height, and Build

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Glossary

Body Mass Index (BMI) – A practical measure of an individual's weight in relation to height, used to define overweight and obesity.

Fat-free Mass (FFM) – Encompasses all of the body's non-fat tissues, including the skeleton, water, muscle, connective tissue, and organ tissues.

Osteoporosis – A condition characterized by low bone mass (density) and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture.

Sarcopenia – A condition characterized by an involuntary age-related decline in lean body mass, primarily due to the loss of skeletal muscle, that affects functional capacity and strength of older adults.

Subcutaneous Adipose Tissue – Adipose tissue between the fascia of skin and the muscles.

Visceral Fat (Intra-abdominal Fat) – A portion of the internal fat in the abdominal cavity lining the intestinal tract.

Introduction

The composition of the human body changes during the entire aging process, from development to maturation and during the advancing years. The sum of the body's components, body weight, also fluctuates during an individual's life span. When changes in the body components occur such as the increase in the amount of fat, then deleterious conditions such as diabetes and cardiovascular disease are manifested. One of the fastest growing segments of the population is individuals over 65 years of age. This age group, which currently accounts for $\sim$15% of the population, is expected to grow to a percentage between 19 and 25% by 2025. Increased body fat and loss of bone mineral density (BMD) and muscle mass are defining characteristics of the aging process. These changes in body composition occur as a result of normal aging, have a detrimental impact on health status, and have substantial economic consequences on the health-care system. Obesity is associated with an increased prevalence of comorbidities, including cardiovascular disease, type 2 diabetes mellitus, hypertension, dyslipidemia, and other metabolic diseases. The decline in skeletal muscle mass

is associated with weakness, functional disability, frailty, and morbidity, whereas the decrease in BMD increases the risk of bone fractures and ultimately results in high rates of disability, morbidity, and mortality in the elderly. This article describes the components of body weight and the various methods currently employed for the determination of body composition. A description of the age-related changes in body composition and how changes in body composition are related to disease will follow.

Body Weight and Its Constituents

Body weight is composed of the sum of the weight of a variety of tissues, the largest component being body water, which comprises approximately 60% of body weight. Body water can be further divided into intracellular (40%) and extracellular (20%) components. For instance, the body weight of a young man may be composed of 60% water, 7% skeleton, 18% protein, and 15% fat. These separate entities differ among individuals and change by gender during the aging process. Furthermore, an excessive increase or loss of various body components is associated with disease. In order to document these alterations and their health consequences, various methods have been developed to assess these changes in body composition.

Body weight is easily and accurately measurable. Recommended body weights as a function of height are based on various tables and provide some aid in assessing obesity. An individual's actual body weight is compared with that of a gender-, stature-, and age-appropriate reference or desirable body weight. The individual's actual weight is then expressed as a percentage of desirable. A desirable body weight in the normal range is usually set between 90 and 120%. Undernutrition and obesity correspond to a body weight below and above these set levels, respectively. An additional method of comparison of weight with a reference population is the calculation of body weight–stature index. This weight–stature index is independent of height and correlates with health outcomes. Since the mid-1980s body mass index tables have replaced actuarial tables to assess obesity.

Body mass index (BMI), a practical measure of an individual's weight in relation to height, is used for diagnosing protein-energy malnutrition and obesity (**Table 1**). A BMI between 18.5 and 24.9 (measured in kg/m^2) is considered normal, with varying levels below this range defined as underweight (17.0–18.5), grade II protein-energy malnutrition (16.0–16.9), and grade III protein-energy malnutrition (<16). A BMI between 25 and 29 defines overweight in adults, whereas obesity is defined as a BMI >30. These criteria for defining overweight and obesity are based on epidemiological evidence that shows a strong association between BMI >25 and an increased incidence of cardiovascular disease, type 2 diabetes mellitus, hypertension, and dyslipidemia that affect mortality and morbidity. Although BMI is a simple index of obesity to obtain, it does not differentiate between fat mass and lean muscle mass. Therefore, it can overestimate body fat in persons who are very muscular and underestimate body fat in persons who have excess fat and reduced muscle mass but normal body weight. Thus, the methods described in the following section are particularly useful in the determination of body composition.

Table 1 Classification of adults according to body mass index (BMI)

Classification	*BMI (kg/m^2)*	*Risk of comorbidities*
Underweight	<18.50	Low (risk of other clinical problems increased)
Normal range	18.50–24.99	Average
Overweight	>25.00	
Pre-obese	25.00–29.99	Increased
Obese class I	30.00–34.99	Moderate
Obese class II	35.00–39.99	Severe
Obese class III	>40.00	Very severe

Adapted with permission from WHO (1999) *Consultation on Obesity* (Technical Report Series 894). Geneva, Switzerland: World Health Organization.

Measurement of Body Composition

Direct measurement of body composition is obtained only from cadaver analysis. Results from these studies provide normative weight data on tissues and organs and are highly accurate. However, indirect methods, developed to accurately assess body composition, can be used repeatedly in clinical and research settings across the age span. The constituents of body composition and the currently available tools for their measurement are discussed in the following subsections.

Total Body Composition

Numerous methods exist for the measurement of total body fat and regional adiposity. In a compartment model for the measurement of body composition, body weight (BW) is divided into fat (F) and fat-free mass (FFM): $BW = F + FFM$. FFM is further divided into five fat-free components, namely, water, osseous and cellular mineral, protein, and glycogen. Most indirect measurements of total body fat are based on compositional differences between the estimated weight of lean and fat tissues and their respective densities. Although FFM and lean body mass (LBM)

are often used interchangeably, they are slightly different. Excluded in the estimated mass of fat is the soluble fat component (i.e., the ether-soluble fraction of the adipose tissue and fat stored in nonadipose tissue sites). Thus, FFM includes the water and protein fractions of adipose tissue. LBM equals BW minus weight of adipose tissue. LBM does not include the weight of water and protein fractions of adipose tissue. The methods that are currently used to make measurements using the two-compartment model are hydrodensitometry, isotope dilution, air displacement plethysmography (ADP), and total body potassium. Methods such as bioelectrical impedance, urinary 3-methylhistidine, and urinary creatinine are other alternatives. A three-compartment model of body composition composed of fat, FFM, and bone mineral content is assessed by dual-energy X-ray absorptiometry (DXA). Whole-body magnetic resonance imaging (MRI) is also used to quantitate adipose tissue in the entire body and lipids in muscle and cells (e.g., liver). For the determination of multi-elemental compartments, neutron activation analysis (NAA), prompt gamma neutron activation analysis (PGNA), delayed gamma neutron activation analysis (DGNA), and inelastic neutron scattering can be used. Regional adiposity and muscle mass are estimated with DXA, computed tomography (CT), MRI, or sonography. A brief description of these various techniques follows.

Hydrodensitometry Hydrodensitometry or underwater weighing, considered for many years the gold standard for measuring body fat, is based upon the Archimedes principle whereby the volume of a mass is equal to the volume of liquid displaced by that solid. Thus, BW in the air and water is measured to determine body density (D_b). Percent fat is determined with the equations described by anthropometry pioneers Siri and Brozek *et al*. as

$$\text{Siri: percent fat} = 4.95/D_b - 4.5$$

$$\text{Brozek } et\ al.\text{: percent fat} = 4.570/D_b - 4.142.$$

Fat mass and FFM are then calculated. Residual lung volume must be determined prior to or during underwater weighing using either the helium or nitrogen dilution methods. Fat and FFM values in adults are assumed to have reference values (0.9007 g/ml and 1.10 g/ml, respectively), which may not be accurate in women, athletes, or the elderly. Furthermore, this technique assumes adequate subject hydration, a fasted state, and a volume of intestinal gas.

Isotope Dilution The measurement of total body water (TBW) is made with the isotope dilution method. The method of TBW is based on the assumption that the ratio of water weight to FFM equals 0.732. Therefore, FFM is calculated as body water/0.732 and fat mass = BW – FFM. Body water may be estimated with the dilution of labeled water using heavy isotopes of hydrogen (deuterium, D_2O) and/or oxygen ($H_2^{18}O$, $D_2^{18}O$) or radioactive water using tritiated hydrogen (^3H_2O), usually administered orally. Measurement of TBW relies on the relationship that C_1V_1 equals C_2V_2, where C_1 is the concentration of the ingested isotope, V_1 is the volume of the ingested isotope, C_2 is the concentration of the isotope in the body after equilibration (as in plasma, saliva, or urine), and V_2 is the volume to be determined or TBW. The concentration of the tracer is measured both before and after its equilibration in the body compartment, and volume is mathematically determined. The assumptions of this technique are that (1) C_2 is completely at equilibrium in each body compartment at the time of measurement, (2) the isotope has not been incorporated with any body constituent other than the tracer (water), and (3) between administration of the tracer and its measurement, there has been a stable state with respect to influx and efflux of the tracee into the water compartments of the body. TBW is overestimated by about 4% for D_2O and ^2H_2O due to the exchange with hydrogen in labile non-aqueous compounds such that the tracer may be lost as the hydrogen breaks off and becomes part of another cellular compartment. With ^{18}O, the stable oxygen of water exchanges with the oxygen of bicarbonate in the blood, and thus $H_2^{18}O$ has an error rate of about 1%. Stable oxygen is very costly and the supply is rather limited. Furthermore, all methods require skilled personnel and sophisticated measuring techniques and equipment.

Air Displacement Plethysmography In ADP, body density is estimated through the measurement of body volume. Body volume is measured through the application of Boyle's law, which states that at constant (isothermal) temperature, pressure and volume are inversely related. Calculation of percent fat is derived from assessment of body volume based on the following equation:

$$\begin{aligned}\text{body volume (l)} = {} & \text{body volume}_{\text{raw}}\ \text{(l)} \\ & - \text{surface area artifact (l)} \\ & + 40\%\ \text{thoracic gas volume (l)}.\end{aligned}$$

After body volume is determined, body density is calculated by dividing mass of the subject by body volume. Thoracic gas volume is measured and

percent fat determined by the Siri equation (as given earlier). This technique, although relatively new, is a valid and reliable alternative to other body composition methods. There are small mean differences between methodologies such as hydrostatic weighing, DXA, deuterium oxide, and multicompartmental methods and ADP. The benefits of using ADP include the short assessment time, ease of use, and propensity for high subject compliance. Specific clothing instructions must be adhered to, to ensure accuracy. Body fat determinations by ADP may be especially useful for geriatric populations. Race does not appear to affect the accuracy of estimating percent fat by ADP. The method has also been validated in overweight and obese individuals.

Total Body Potassium Total body potassium (TBK) is used to estimate LBM because the ratio of potassium (K) to LBM is relatively constant. From cadaver and *in vivo* studies, the ratio is generally accepted to be 68.1 mEq K/kg LBM in men and 64.2 mEq K/kg LBM in women. In this method, ^{40}K, a naturally occurring radioisotope, is detected by a sensitive gamma ray detector placed close to the subject in a heavily shielded room. TBK is then mathematically determined from the measured ^{40}K. Although this method has an accuracy of approximately 3–4% and is non-traumatic and non-invasive, it is very expensive and technical. It should also be noted that measurement of ^{40}K may be erroneous in potassium-depleted states.

Anthropometry Anthropometry values, such as those obtained by thickness and limb circumferences, can be used in multiple regression equations to predict body density and to calculate body fatness and FFM. Skinfold thicknesses can be taken in several sites, such as bicep, tricep, suprailiac, subscapular, thigh, and abdomen. The measurement of thickness is based on two assumptions: (1) the thickness of the subcutaneous adipose tissue reflects a constant proportion of the total fat and (2) the sites selected for measurement represent the average thickness of the subcutaneous adipose tissue. The validity of using equations to predict body composition is restricted to populations from whom these equations were derived. Other contributing factors to error in this technique include the biological variation in fat in other depots such as intermuscular, intramuscular, and fat surrounding organs and the gastrointestinal tract. There is some evidence to suggest that equations need to be established that are specific for race. For additional information on anthropometry, a comprehensive manual provides details for measurement procedures and standardized techniques for more than 40 anthropometric measurements.

Bioelectrical Impedance Bioelectrical impedance (BIA) is based upon the assumption that fat acts as an insulator and FFM conducts electrical current. Body fluids and cell membranes are responsible for conductance and capacitance (low impedance), respectively, whereas bone, fat, and triglyceride are non-conductive and have high impedance. BIA is based upon the principle that the impedance of a geometrical system is related to conductor length and configuration, its cross-sectional area, and signal frequency. The impedance of the flow can be described as $Z = aL^2/V$, where Z is impedance in ohms, a is volume resistivity in ohms-centimeters, L is conductor length in centimeters, and V is volume in liters. Impedance can be partitioned into its components, resistance (R) and reactance (Xc): $Z^2 = R^2 + Xc^2$. Electrodes are placed at the wrists and ankles (hand-to-foot BIA), a small current is introduced, and the resistance to the current is measured. Appropriate regression equations are used to predict FFM and hence fat mass from BW. Prediction equations generally include other parameters such as age, gender, body circumferences, and skinfold thickness. New BIA systems utilize a foot-to-foot BIA system and resemble a bathroom scale. These systems have been validated in older adults for percent fat estimates against underwater weighing, DXA, and hand-to-foot BIA. An important assumption for BIA is a balanced hydration state; either dehydration or fluid overload reduces the accuracy of FFM.

Dual-Energy X-Ray Absorptiometry DXA allows separation of body mass into bone mineral, fat tissue, and fat-free soft tissue, a three-compartment model. DXA has an X-ray source with two photon energies including low and high energy levels. The ratio of high to low energy attenuation is specific to elements (e.g., hydrogen, which minimally attenuates photons, or calcium, which is highly attenuating). A measure of the soft tissue attenuation at the two energy levels is referred to as the Rst. The Rst correlates inversely with the proportion of soft tissue as fat. The X-ray beam scans on a pixel-by-pixel basis over the body, and the values for all pixels are summed to estimate the molecular components for the body. DXA results are highly correlated with criterion methods, but there is modest systematic variation in the estimates of body composition by DXA with the use of different hardware and software accommodations to the interpolations for soft tissues located over bone and the treatment of pixels for which a small portion is bone. There are newer and faster fan beam instruments that

may have error in the beam magnification due to the variation in heights between the source and detector of tissues. There is some evidence that certain DXA machines may overestimate FFM and underestimate FM. Radiation exposure and scanning time have been reduced with the newer DXA machines. The ease that DXA affords the subject makes it an attractive alternative for body composition assessment in the elderly or those who may fear submergence in the water with hydrodensitometry. Studies that report comparisons across different DXA machines suggest that the same system be used in longitudinal studies examining changes in percent body fat and BMD. However, comparisons of pencil beam versus fan beam DXA machines illustrate comparable and interchangeable results for appendicular lean soft tissue.

Urinary 3-Methlyhistidine and Creatinine Excretion Muscle mass analysis can be determined by techniques such as urinary 3-methlyhistidine (3-MH) excretion and urinary creatinine excretion. Creatinine and 3-MH are end products of muscle metabolism that cannot be further metabolized. They are excreted quantitatively in the urine and are directly proportional to muscle mass. High-performance liquid chromotography is conducted to determine a peak value of absorption of these products. Day-to-day variability, complete and accurate urine collections, and the need to comply to a meat-free diet prior to analysis are requirements of these methods that limit the accuracy of this technique.

Neutron Activation Analysis Neutron activation analysis (NAA) is the only technique available for the measurement of the multi-elemental composition of the body. In general, a moderated beam of fast neutrons is delivered to the subject. Unstable isotopes are created and are reverted to a stable condition by emission of one or more gamma rays of characteristic energy. The induced radioactivity is measured in a whole-body counter. The energy level identifies the element and the level of activity indicates its abundance. Neutron activation can be used for determination of Ca, K, P, N, Mg, and Na. Specifically, a method known as prompt gamma neutron activation (PGNA) analysis measures total body nitrogen. Nitrogen (^{14}N) is excited to ^{15}N and gamma rays. Delayed gamma neutron activation (DGNA) analysis allows the measurement of total body mineral through the excitation of ^{48}Ca to ^{49}Ca and gamma rays. Using appropriate equations, total body fat can be calculated with the estimation of total body protein by PGNA, bone mineral by DGNA, and body water by isotope dilution. Another system, inelastic neutron scattering, can provide an estimate of total body carbon. A miniature deuterium-tritium accelerator generates fast neutrons that result in gamma rays produced from ^{12}C. The model assumes that total body carbon is distributed to a certain percent in fat, protein, glycogen, and bone ash. Using the measurement of total body carbon, nitrogen, and calcium, total body fat can be estimated. Although NAA can provide valuable information, it is very costly and requires a high radiation dose and highly skilled investigators, and presently there are few facilities in the world where it can be performed.

A modification of this method uses simultaneous measurements of the ratio of body carbon to oxygen with large (bismuth-germanium-oxygen [BGO]) crystal detectors. The signal-to-background ratio for the carbon detection is vastly improved (sixfold) compared to the sodium iodide (Tl) detectors, and the method also allows for the measurement of regional body fat. The basis for this modification is the large differences in carbon and oxygen content between fat and lean tissue. The technical aspects of this modification have been published, and its accuracy has been validated against hydrodensitometry in humans. Additional advantages include a significant reduction in radiation exposure (much less than a chest X-ray) and cost of operation (by more than two-thirds).

Regional Assessment

Computerized Tomography Regional adiposity and skeletal muscle mass can be determined with CT. This approach relates small differences in X-ray attenuation to differences in the physical density of tissues. The scanner computer constructs a two-dimensional image of the underlying anatomy in the scan area. The cross-sectional area of adipose, bone, and muscle can be determined for each image. Because thickness is known, relative surface area or volume can be calculated. Furthermore, CT scans of the abdominal region, typically performed at the L_4–L_5 region, assess both subcutaneous and intra-abdominal (visceral) adipose tissue and are highly accurate (**Figure 1**). Subcutaneous abdominal adipose tissue can be partitioned into the plane superficial to the fascia within subcutaneous adipose tissue (termed superficial subcutaneous abdominal adipose tissue) and below this fascia (termed deep subcutaneous abdominal adipose tissue) (**Figure 1**). There are morphological differences between the two layers as well as differences in the proportion of each layer by gender, with a greater proportion ($\sim$65%) of deep subcutaneous abdominal fat in men vs. about 50% for each layer in women. These layers of

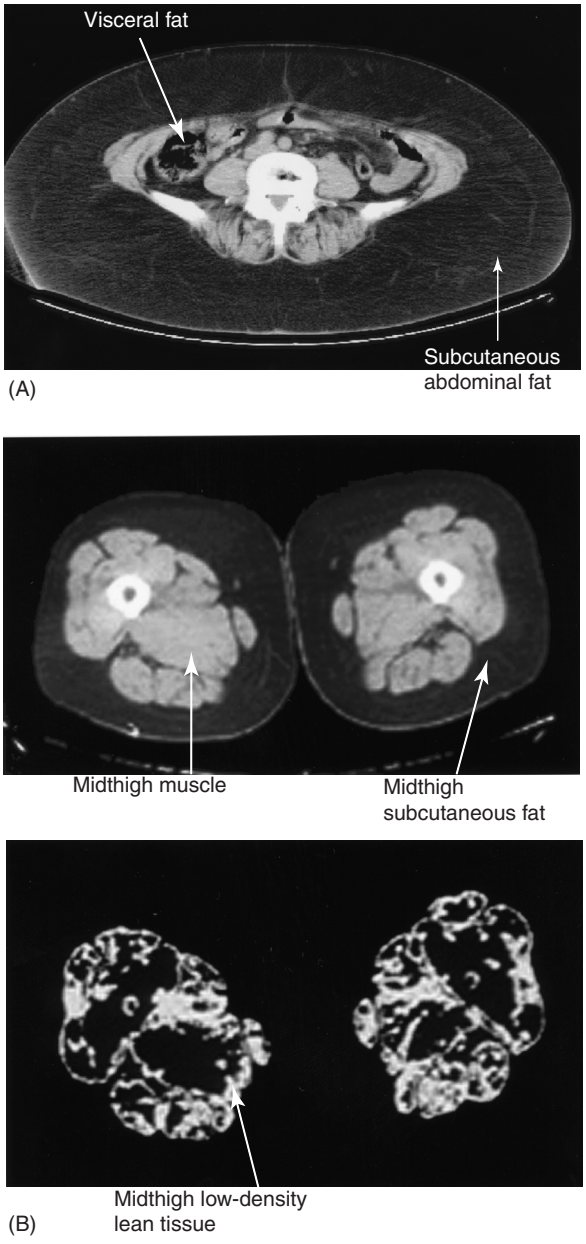

Figure 1 Cross-sectional images from the abdomen at L_4–L_5 (A) and midthigh (B) in a postmenopausal woman.

subcutaneous abdominal adipose tissue are associated with the metabolic complications of obesity. CT is also used for measurement of muscle area, subcutaneous fat, and low-density lean tissue in the thigh (**Figure 1**), calf, or other regions of interest. The CT-derived lipid within skeletal muscle, or low-density lean tissue, is determined by a reduced muscle attenuation. Because of the relatively greater exposure to ionizing radiation compared to DXA, routine whole-body scans and multiple scans in the same individual limit the use of CT. Researchers have lowered the radiation dose and have applied multiple scan slices across the total body in order to estimate total body fat.

Magnetic Resonance Imaging MRI also quantitates total fat mass and discriminates differences in regional fat and muscle tissue. MRI is based on the principle that atomic nuclei behave like magnets. An external magnetic field is applied across a part of the body. Each nucleus or magnetic moment attempts to align with the external magnetic field. A radio frequency wave is used simultaneously to rotate the nuclei to the magnetic field. The absorbed energy from the activated nuclei is released when the radio frequency is shut off. This radio signal is used to develop an image and thus a clear determination of adipose and muscle tissue. In contrast to CT, MRI does not use ionizing radiation. Its restricted availability and high cost also limit its use in body composition assessment. Whole-body MRI can be performed to assess adipose tissue and muscle areas. Acquisitions are typically taken at 40-mm intervals across the whole body with $\sim$40 axial images (10 mm thickness) obtained. MRI is also used to quantify intra-abdominal adipose tissue and subcutaneous fat of the abdomen as well as appendicular muscle mass. MRI volume estimates can be converted to mass using assumed densities for skeletal muscle and adipose tissue. The amount of intermuscular adipose tissue in the total body is about the same size as visceral fat in adults as determined by whole-body MRI. Intermuscular adipose tissue is not the same as intramyocellular lipid (lipid within muscle fibers). Intramyocellular lipid is quantifiable by single- and multivoxel magnetic resonance spectroscopy (MRS) from muscles such as the tibialis anterior.

Sonography To determine abdominal fat using ultrasound, the patient lies in a recumbent position and subcutaneous thickness and intra-abdominal fat are measured next to the umbilicus in the xypho-umbilical line. Either a 5-mHz or a 7.5-mHz transducer is used to measure subcutaneous fat thickness, whereas intra-abdominal fat is measured using a 3.3-mHz transducer. Using images on the screen, the thickness of subcutaneous fat is measured with calipers placed at the skin–fat and fat–muscle interfaces, and that of visceral fat is measured at the internal face of muscle and the anterior wall of the aorta. Both subcutaneous and visceral fat as determined by ultrasound are significantly correlated with that determined by CT in obese women across the age span. Sonography requires a skilled operator, but it is safe, is noninvasive, and does not involve radiation exposure, and the imager is widely available.

Anthropometrics The waist circumference is used to estimate central obesity. A waist circumference >102 cm in men and >88 cm in women classifies abdominal obesity by the Adult Treatment Panel III criteria. The regional distribution of fat can be estimated by the ratio of waist circumference to hip circumference (WHR). A WHR of >0.90 in men and >0.85 in women is generally considered to be upper body obese, and a WHR below these numbers is considered as lower body obese. Waist circumference and WHR correlate with CT and MRI analysis of abdominal tissue. Other simple measures of regional obesity can be made with circumferences as well as depths and breadth measurements from other parts of the body. Several researchers have developed predictive equations with the use of CT as the criterion method to estimate visceral fat. These equations utilize simple anthropometry, DXA measures, and the combination of the two to estimate visceral fat. Reports indicate that skinfold thicknesses should not be used to assess changes in body composition with age due to their failure to detect fat distribution changes with age.

Change in Body Composition with Aging

Prevalence of Overweight and Obesity

The National Center for Health Statistics has examined the prevalence and trends of overweight adults in the United States from 1960 to 2000 via the National Health Examination Survey (NHES I) and National Health and Nutrition Examination Surveys (NHANES I, II, III, continuous). The prevalence of overweight and obesity increased significantly over a 40-year period, from 43% in 1960–62 to 64.5% in 1999–2000. Most of this increase is attributable to a dramatic rise in the prevalence of obesity (BMI $>30\,kg/m^2$), which remained stable at $\sim 15\%$ for the first three survey periods (1960–80), and then rose dramatically to 30.5% in 1999–2000. The increased prevalence of overweight and obesity in adults during this time period was evident in both genders, across all races and ethnicities, and across all age groups.

Change in Body Weight and Fat Mass with Aging

In healthy people, body weight increases gradually from early adulthood until the fifth to sixth decade of life and then remains stable until age 65 to 70. During the period of weight gain, body weight increase occurs at a rate of 0.39 to 0.45 kg/year for women and 0.36 to 0.41 kg/year for men, irrespective of race. The slightly higher rate in women compared to men suggests that the transition from pre- to postmenopausal status affects the amount of weight gain. After age 60, body weight decreases slowly at a rate between 0.05 to 0.36 kg/year, depending on race and gender. The rate of decrease is usually higher in women compared to men, regardless of ethnicity. Moreover, the rate of body weight decrease is highest in African American women and lowest in African American men. The variation in body weight regulation suggests that a non-linear pattern of weight change occurs through the aging process.

The pattern of weight gain is generally consistent between cross-sectional and longitudinal studies and is characterized by a greater increase of fat than lean mass accounting for the increase in body weight. The relationship between age and body fat is curvilinear, with the greatest increase in body fat occurring in middle-aged persons and smaller increases occurring in both the young and the elderly. That is, there is a pattern of increasing fat mass with age until 50–69 years, followed by a slow decline in fat mass in older age groups (>70 years). However, irrespective of the age group, 7–31% of the variation in the increase in fat mass (absolute or relative) in the adult population is accounted for by age.

The increase in weight with age is accompanied by an age-related redistribution of fat to the abdominal region. Sedentary women in their fifth decade of life have an average 1.5- to 3-fold higher visceral and subcutaneous abdominal fat areas compared to their younger counterparts and athletes of similar age. Similarly, older women athletes in the fifth and sixth decade of life have a two- to threefold higher visceral fat area compared to younger athletes despite similar BMI and percent body fat. Therefore, there is an accumulation of fat in the abdominal region during the aging process irrespective of physical activity status. However, maintaining an active lifestyle partially negates the consequences of aging by dramatically reducing the amount of abdominal fat deposition. The ability to alter the accumulation of fat in the abdominal region is of clinical significance when one considers that intra-abdominal fat areas greater than $100–110\,cm^2$ increase the risk for developing cardiovascular disease and other metabolic diseases. The age-associated increase in visceral adiposity may contribute to the increase in triglyceride and total cholesterol concentrations and to glucose intolerance with age.

An increase in the infiltration of fat around and within skeletal muscle occurs with aging and adversely influences glucose and lipoprotein metabolism. CT scans document a twofold increase in mid-thigh subcutaneous fat between pre- and postmenopausal sedentary women. Moreover, there is also a twofold

increase in low-density lean tissue, a marker of intramuscular fat. Approximately 27–33% of the variation in the increase in mid-thigh subcutaneous fat and low-density lean tissue areas in the mid-thigh region is accounted for by age. Cross-sectional studies report increases in intramyocellular lipid and liver fat in older versus younger adults. Longitudinal studies also demonstrate increases in visceral adipose tissue and intermuscular adipose tissue with age. The contribution of intramuscular fat to the metabolic dysfunction associated with the insulin resistance syndrome may help explain racial difference in glucose metabolism.

Change in FFM and Its Constituents with Aging

As body weight and fat mass increase with aging, total FFM and its constituents (skeletal muscle mass, body cell mass, total body water, and bone mineral mass) gradually decrease. Peak FFM in males is reached in the mid-30s and then progressively declines. In females, FFM remains relatively stable until approximately age 50, then the decline in FFM occurs at a slower rate than males. The average loss of FFM is approximately 16% between the ages of 25 and 70 in both men and women at a rate of $\sim$0.16 kg/year. Since skeletal muscle accounts for more than half ($\sim$55%) of total FFM, the decrease in skeletal muscle mass between the ages of 20 and 70 is slightly lower than the loss of FFM at 10 to 15%, with the rate of decline greater in men (0.8 to 1.9 kg/decade) than women ($\sim$0.4 to 1.1 kg/decade). Although the relative decrease in FFM starts during the third decade, skeletal muscle mass is preserved until the fifth decade, with a noticeable decrease in absolute skeletal muscle mass occurring at $\sim$45 years in both men and women. Some studies suggest that the loss of skeletal muscle mass may be accelerated in individuals $\geqslant$70 years of age. In addition, the Health, Aging and Body Composition Study shows that changes in body composition with age are related to weight loss or gain and to baseline body composition. Specifically, there is a greater tendency to conserve the lean compartment than the fat compartment with weight change in generally healthy older (70–79 years) men and women, but after adjustment for selected variables, there remains the failure to conserve lean mass with weight loss in old age. In addition to changes in whole-body muscle mass, muscle cross-sectional area declines by 1.4%/year in older men (age 65 at baseline) who were followed for 12 years.

The involuntary age-related decline in FFM, primarily due to the loss of skeletal muscle, is termed sarcopenia and affects functional capacity and strength of older adults. Sarcopenia has been defined in older adults as a height-adjusted appendicular muscle mass of two or more standard deviations below the mean of young adults or as muscle mass relative to body weight. The prevalence of sarcopenia varies from 6 to 24% in persons under 70 years of age to $>$50% in persons over 80 years of age, depending on the definition and measure of muscle mass. The metabolic effects of sarcopenia include a decline in resting metabolic rate secondary to decreased FFM and decreased physical activity.

The loss of skeletal muscle mass is strongly associated with a loss of body water, because a large proportion of skeletal muscle ($\sim$75–80%) is water. Total body water accounts for approximately 80% of FFM at birth. In young adults, TBW comprises approximately 72% of FFM. Thus, a loss of body water occurs until maturity but remains relatively constant throughout adulthood and middle age. TBW on average is lower in females than in males. Losses of body water occur after age 70 in females and somewhat earlier in males, with a nadir at 70–80 years. The decline in TBW suggests a change in the hydration of the fat-free compartment (increased with normal aging). The extracellular water compartment (ECW), when expressed as a ratio to body weight, intracellular water (ICW), or FFM, is at a maximum in early life, reaches a nadir in the early adult years, and again increases in old age. The ECW:ICW is larger and ICW is smaller with increasing age after adjustment for race and body composition. Research suggests that the largest age-related differences are observed in African Americans compared to Caucasian, Asian, and Hispanic individuals. TBK, an index of FFM, begins to decline at approximately age 30 for men and women. Values are highest in African Americans, followed by Caucasians, Hispanics, and Asians. The decline in TBK is most rapid in African American women and Hispanic men, suggesting that there are significant gender and racial differences in the decline in FFM with age.

In addition to the losses of FFM, skeletal muscle mass, and TBW with age, the loss of bone mass is consistently documented. Peak bone mineral mass is reached at age 20–30 followed by a progressive decline. By age 70, spinal and femoral neck BMD is diminished by approximately 20 and 25%, respectively. Furthermore, the rate of bone loss varies with site and may be greater in areas with more trabecular bone than in areas of predominantly compact bone. Total body mineral may decline at a slower rate than that observed in specific sites. In women, a more dramatic loss of bone mass occurs during menopause. The rate of BMD loss is greater

among perimenopausal women compared to pre- and postmenopausal women and is site-specific. Longitudinal studies estimate the rate of premenopausal BMD loss at 0.7–1.3%/year at the lumbar spine and 0.2–0.3%/year at the femoral neck. In contrast, the rate of BMD loss for perimenopausal women is 2–3%/year at the lumbar spine and 0.6–1%/year at the femoral neck. The estimated loss of BMD at the lumbar spine and the femoral neck is 1.3–1.5%/year and 1–1.4%/year in postmenopausal women, with the fastest rate of bone loss occurring immediately after menopause.

The rate of osteoporotic fracture risk is higher in women compared to men, such that the rate of loss in BMD for men is two-thirds the rate of women in the spine, and one-half the rate at the femoral neck. Despite these differences, an age-related increase in fractures associated with osteoporosis is evident in men as well. The slower rate of bone loss results in a lower prevalence of osteoporosis in men ($\sim$6%) compared to women ($\sim$20%), as well as an incidence of hip and vertebral fractures in men older than 65 that is approximately half that of women of similar age. Relative risk is also site-specific, and regional adiposity specifically in the hip may be protective against fracture. Many factors influence both peak bone mass and its loss, including nutritional state, physical activity levels, disease (e.g., hyperparathyroidism), genetics, certain drugs (e.g., glucocorticoids, anticonvulsants), alcoholism, smoking, immobilization, and hormonal status.

Body Composition and Relationship to Disease

The changes in body weight and composition associated with aging have major public health implications. Obesity is a major risk factor for coronary heart disease, congestive heart failure, stroke, ventricular dysfunction, and cardiac arrhythmias. The increase in total and abdominal obesity is associated with increased risk for developing cardiovascular disease, type 2 diabetes, hypertension, dyslipidemia, and other metabolic diseases. A new important treatment for obese class III is bariatric surgery, which reverses many of these metabolic diseases. Obesity is also associated with altered pulmonary function and increased inflammatory state. Importantly, approximately 300 000 deaths a year may be attributable to obesity, with an estimated cost to the health-care system of over $100 billion/year.

The risk of cardiovascular disease is higher in the overweight and obese. In age-adjusted analyses of $\sim$18 000 middle-aged men with coronary heart disease, there is a modest elevated risk in the overweight relative to normal weight groups for all-cause mortality and coronary heart disease mortality but not stroke mortality. Similar results are obtained in obese groups, suggesting that obesity and overweight in adult life contribute to risk of total and coronary heart disease mortality. In a nationally representative survey of the US population (Medical Expenditure Panel Survey [MEPS]), the likelihood of having diabetes and diabetes-related cardiovascular comorbidities increased with BMI regardless of physical activity and increased with physical inactivity regardless of BMI. The multivariate-adjusted odds ratio for diabetes was 1.52 for normal weight inactive adults and 1.65 for overweight inactive adults. Thus, both physical inactivity and obesity are strongly and independently associated with diabetes and diabetes-related comorbidities.

In addition to the detrimental effects of total body adiposity, the location of the fat also plays a role in determining the influence of the fat on risk factors for disease. The CT-derived lipid within skeletal muscle is directly related to age and adiposity in women and is associated with insulin resistance and lower extremity dysfunction in older adults.

Low muscle mass impacts the health, independence, and welfare of older persons. Sarcopenia is associated with a three- to fourfold increase in functional impairment, disabilities, and falls in the elderly. Specific cut points have been proposed that are associated with elevated physical disability risk in older persons. Given the economic burden of physical disability on health-care systems, it is likely that sarcopenia contributes to these health-care costs.

The age-related decline in BMD results in a decrease in bone mass and strength that may lead to osteoporosis or an increase in fractures in the vertebral bodies, femur, and distal radius. As an example, the risk of hip fracture triples with each 10% decrease in femur BMD. Because men have higher bone mass than women throughout the life span, and BMD declines at a slower rate in males than females, the incidence of osteoporosis is lower in males. Osteoporotic fractures generate substantial cost due to acute hospitalization and subsequent rehabilitation at an estimated cost of $17 billon/year and, like obesity, increase morbidity and mortality (e.g., 12% mortality rate during the first year after a hip fracture).

In summary, the age-related changes in body weight and body composition are associated with a number of diseases. These changes, which can be documented by a variety of methods currently available depending upon the resources and the population being studied, are influenced by nutrition, activity, genetics, and economic and social concerns. Lifestyle behavior changes such as proper nutrition,

increased regular physical activity, and intentional weight loss reduce the risk for developing metabolic and cardiovascular diseases. For example, caloric restriction to induce weight loss with or without an exercise training program reduces the incidence of developing type 2 diabetes and improves the cardiovascular risk profiles in obese individuals. Furthermore, physical activity may help mitigate the tendency for weight gain and adverse changes in body composition and fat distribution that accompanies aging. Aerobic and resistive exercise training programs greater than 6 months in duration maintain or increase muscle and bone mass and in effect may prevent the progression to sarcopenia and osteoporosis. With epidemiological studies documenting an increase in the average life span, structured behavioral programs that include nutrition and exercise should be recommended to alter the adverse body composition changes observed with aging.

See also: Cardiovascular System; Exercise and Physical Activity; Osteoporosis and Aging Related Bone Disorders.

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Brain and Central Nervous System

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Glossary

Astroglia – A population of non-neuronal cells with numerous, branching processes that provide mechanical and functional support to central nervous system neurons.

Hippocampus – A region of the brain located in the medial part of the temporal lobe and concerned with memory.

Locus Ceruleus – A group of pigmented neurons in the roof of the pons that is the principal source of the noradrenergic innervation of cerebral cortex.

Nucleus Basalis of Meynert – A collection of neurons in the orbital frontal part of the brain that is a major provider of cholinergic innervation for the cerebral cortex.

Synapse – Point of junctional contact between neurons where electrochemical signal is transmitted.

Introduction

Although age-related changes in the human brain are readily demonstrated, it is always difficult, and in most cases impossible, to know how much of those changes are due to aging per se. Elderly humans are afflicted acutely with numerous age-related diseases and suffer the cumulative affects of numerous other chronic illnesses. They are affected by neuroactive medications used to treat their acute diseases and by the cumulative effects of other neuroactive substances, such as alcohol and caffeine. The effects of an increasingly hostile environment are often not easily differentiated from those due to the effects of aging on the structure and chemistry of the brain.

Age-related changes in brain functions are also readily demonstrated, and at least some of these appear to reflect the process of aging rather than environmental change. Age-related changes include changes in secondary memory, reaction time, visuospatial memory, complex attention, language fluency, and problem solving. Neurobiological substrata of these cognitive changes are unknown and their elucidation is the raison d'être of gerontological research.

Gross Anatomy of the Aging Brain

Structural changes due to aging in the brain have been characterized on three organizational levels. At the level of gross structure, changes in brain weight, based on measurements made after death, are significant. Although the amount is uncertain because of postmortem changes in fluid compartments, the loss is nonetheless probably in the order of 10%. Changes in brain volume are probably most reliably assessed on the basis of imaging – computed tomography (CT) or magnetic resonance imaging (MRI). Imaging shows the cerebrospinal fluid volume to be relatively constant in young adults to about age 40; then it begins to increase, especially after age 60. The brain, which occupies more than 90% of the cranial cavity between ages 20 and 50, occupies progressively less after age 50. In older adults, then, there is a significant decrease in brain-to-cranium volume and an increase in cerebrospinal fluid volume of about the same magnitude. Regional decrements in brain volume have been reported in frontal and temporal lobes, cerebral cortex, basal ganglia, corpus callosum, and hippocampus.

Microscopic Anatomy of the Aging Brain

Neuronal Death

At a microscopic level, decrements in numbers of neurons with age are well documented but not without controversy. Neuronal loss does not occur uniformly throughout the brain but occurs in selected areas, and is often difficult to evaluate because of technical limitations. These include methodological limitations of microscopic morphometry, uncertainties in differentiating neuroglia and neurons, transient neuronal atrophy as a result of which some neurons cannot be seen with a conventional light microscope. Nonetheless, in humans decreases of 15 to 57% are reported in cerebral cortex from selected gyri of the frontal, temporal, parietal, and occipital lobes, and comparable decrements are reported for locus ceruleus, substantia nigra, cerebellar Purkinje cells, and hippocampal pyramidal neurons. Neuronal loss can be regionally specific, as in the hippocampus where significant loss is reported in area CA4 and the subiculum, but not in the dentate, CA1, or CA2. Neuronal loss in the human nucleus basalis of Meynert is less certain and still less certain in other regions, although seemingly reliable decrements are reported in rodents. Decreases in the number of

synapses and perhaps in the number of dendrites are other morphometric indicators of neuronal malfunction in the aged brain. Like neuronal loss, they too may be better documented in laboratory animals than in the human brain.

Neuronal Injury

The metabolic failure of neurons and neuronal systems in old age need not require actual loss of neurons, neurites, or synapses. Neuronal atrophy and hypertrophy have both been reported as characteristics of aged neurons. Neuronal atrophy in the nucleus basalis of Meynert has been described in some rodents. In other rodent strains and in old humans these cholinergic neurons appear to hypertrophy. Neuronal atrophy in the infundibular nucleus in older men and postmenopausal women has been ascribed to the loss of steroid negative feedback. Other indications of compromised neuronal function might include the accumulation of lipofuscin and neuromelanin. Although there is no convincing evidence that the accumulation of these substances is neurotoxic, the accumulation of lipofuscin has the appearance of crowding out organelles involved in synthesis and transport, and neuromelanins can bind potential toxins such as 1-methyl-4-phenylpyridine.

Age Changes in Neurotransmitters

Morphometric changes (see above) indicate changes in the aged human brain in neurotransmitters and in interneuronal communication. There is, for example, a well-documented central cholinergic deficit in animals. In humans, deficits in choline acetyl transferase activity are reported in hippocampus, entorhinal cortex, frontal cortex, and cerebellum, and a decreased density of cholinergic fibers in amygdala has been found in older adults. Relatively little is known about cholinergic receptors, especially nicotinic receptors in the aged brain. However, muscarinic receptors appear to be decreased in the human brain, and significant decrements are reported in cerebral cortex and striatum and hippocampus in old rodents. Changes in noradrenergic and seratonergic transmission are not well defined. Norepinephrine is reportedly reduced in the aged human brain, and dopamine may be reduced in the caudate nucleus. However, in more adequately controlled studies, norepinephrine and dopamine turnover are reportedly unchanged, whereas seratonin turnover is increased in old rats. Reduced regional seratonin concentrations with no accompanying decrease in 5-hydroxy indoleacetic acid levels have been found in aged human brains. These are believed to result from decreased metabolism of the indolamine precursor, coupled with a compensatory increased metabolic activity in surviving terminals that maintains functionally normal levels of the transmitter in nerve terminals. Glutamergic function appears to be relatively stable in old age.

Age Changes in the Neuronal Microenvironment

Although they remain unexplored in the elderly human brain, changes in the extracellular neuronal microenvironment with age, which are primarily known from animal studies, can reasonably be predicted to effect neuronal aging in humans (*see* Models of Aging: Vertebrates). Their functionally important relationships with age changes in neurotransmission are outlined in **Figure 1**. The neuronal microenvironment consists, primarily, of vascular elements and extracellular space, all of which appear to change with age. A decreased extracellular space, demonstrated in the brains of old rats, may serve to limit the diffusion of metabolites and, perhaps, transmitter substances in the aged brain. Age changes in

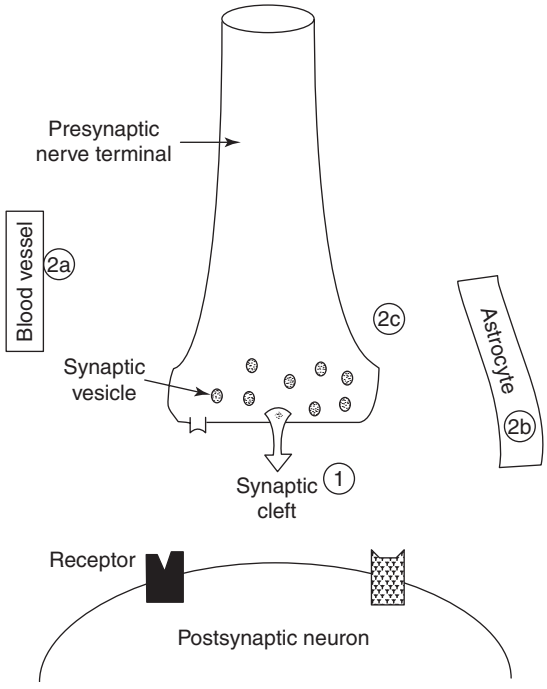

Figure 1 Age changes in the brain include (1) selective decrease in the amount of neurotransmitter substance available for neurotransmission and decrease in certain receptors, and (2) changes in the neuronal microenvironment, such as endogenous changes in the cerebrovasculature (a), astroglia (b), and extracellular space (c) that compromise neuronal nutrition and interfere with the interaction between transmitter substances and receptors.

the extracellular space have barely been investigated in the human brain. Changes in the cerebral vasculature are legion, but changes in the human brain microvasculature with age are poorly understood. Changes due to aging in cardiovascular tissues add to changes due to degenerative diseases in the same manner as age changes add to changes resulting from neurodegenerative diseases. Aging, thereby, accelerates vascular degenerative diseases with the result that systolic blood pressure and low-density lipoprotein (LDL) cholesterol increase with age and older persons are at increased risk for cerebroischemic vascular disease. Changes of vascular tissues due to aging include the decreased production of endogenous vasodilatory agents and alterations in the structure and distribution of collagen, elastin, and glycosaminoglycans. The effects of these changes on the aged brain are unknown, but likely sequelae of such changes would include interference with neurotransmission and myriad disturbances in neuronal metabolism.

It can be anticipated that age changes in the microvasculature might affect electrolytes mediating neuronal electrochemical activity. Although no changes in Na^+/Ca^{2+} exchange activity and Ca^{2+} permeability were found in a study of human frontal cortex, studies of rodent brain do reveal age changes in inositoltriphosphate receptor Ca^{2+}-release channels and calcium-mediated after-hyperpolarization. Adenylate cyclase activity, oxidative phosphorylation, mitochondrial electron transport mechanisms, and DNA metabolism all appear impaired in old rodent brains. Changes such as these, if not reflective of programmed changes in the neuronal genome, may reflect age changes in the neuronal microenvironment. It is unknown whether such changes, whatever their origin, are of sufficient severity to abolish such dynamic neuronal functions as those involved in synaptic plasticity.

The role of astroglia in the process of aging remains unclear. Astrocytic end feet contribute to the neuronal microenvironment in that they help separate neuronal and extracellular (vascular channels and extracellular space) elements. They contribute to the isolation of synaptic complexes, such as represented by cerebellar glomeruli. They can occupy space resulting from the loss of neurons and segregate pathological materials, such as degenerating extracellular neurofibrillary tangles. Astrocytes express apolipoprotein E and probably produce neurotrophic factors. They may play a role in neuronal metabolism and assist the plastic neuronal response to injury by facilitating nutrient transport. Hypertrophy of the astrocytic compartment with no accompanying increase in the number of astrocytes in old age has been demonstrated in rats, but it is not known how this might aid or inhibit processes associated with aging.

Neuronal Plasticity in the Aged Brain

Axons are regenerated more slowly in old animals, but neurons in aged brains retain the capacity for synaptic plasticity. They react to the effects of trauma or metabolic insult by replacing lost synapses with new ones, although the regenerative process may be delayed in old animals. As long as there is accurate replacement of lost connections, neuronal plasticity appears to be a continuous dynamic process underlying the capacity to form and destroy circuits continually as new material is learned or forgotten. However, aberrant axonal sprouting or erroneous replacement of synapses can also lead to faulty circuitry and environmentally non-adaptive behavior. It is unclear how much of this neuronal plasticity depends upon the presence of nerve growth factors (NGF), as NGF has been shown to improve performance on spatial memory tests when injected into the region of the nucleus basalis of Meynert in aged rats. The expression of NGF appears to be preserved in old age.

Neuropathology of Aging

A number of changes characteristic of specific neuropathological disorders are found in the aged human brain, but in smaller numbers or attenuated form. Atrophic changes in gross structure such as ventriculomegaly and sulcal widening, which are characteristic of neurodegenerative diseases often associated with dementia, are found in non-demented, apparently normal elderly persons. Although some persons showing MRI signs of cortical atrophy may be cognitively impaired, some may not be, and there is no convincing evidence that such findings herald the later development of a progressive dementing disorder. The demonstration by MRI of numerous, voluminous lesions in the periventricular white matter is, similarly, usually associated with neuropathology, although the presence of lesions of lesser number and amount is a common finding in old people who show no significant cognitive impairment, are not demented, and may never develop a dementing disease (*see* Dementia).

Microscopic neuropathological changes often found in the aged human brain include senile plaques, β-amyloid (BA) deposits, neurofibrillary tangles, and granulovacuolar degeneration complexes. These may be more numerous in the hippocampus, but they occur throughout the brain in old

age in smaller numbers. Again, their presence may be associated with impaired cognition or psychopathology, but in many cases there is no apparent pathology and no abiding evidence that such lesions represent an early stage or attenuated form of a progressive dementia such as Alzheimer's disease.

Neurofibrillary tangles and senile plaques, when they are found in non-impaired, apparently normal older adults, may be indicators of pathological aging. This refers to the presence of abnormal findings that hasten or intensify the process of what is conventionally termed normal aging. The concept of pathological aging is illustrated by a recent study of demented older adults in whose brains it was possible to demonstrate cytoplasmic structures containing ubiquitin-bound protein. These microscopic-size structures, called Lewy bodies, are characteristic findings in Parkinson's disease and a non-Alzheimer's disease dementia. They were found in the cerebral cortex unaccompanied by plaques and tangles in very few cases in which dementia was mild. They occurred more frequently in addition to abundant senile plaques and neurofibrillary tangles with more severe dementia. It can be assumed that the presence of abnormal aging will intensify the effects of a neurodegenerative disease and vice versa.

Senile plaques consist of dystrophic neurites and BA protein. The dystrophic neurites contain an abnormal form of tau protein that is aggregated so as to form paired helical filaments (PHF). These PHFs are further aggregated to form the neurofibrillary tangles occasionally found within pyramidal neurons or found extracellularly in the hippocampus in non-demented older adults. They are rarely found in the cerebral cortex in older, cognitively normal adults. Normal tau protein is not aggregated in PHFs but bound to tubulin in microtubules that are, thereby, stabilized and able to participate in intraneuronal transport. Abnormal tau protein, presumably because it is hyperphosporylated, is unable to bind with tubulin, which destabilizes microtubules and disrupts transport systems. There is evidence of slowed septalhippocampal axonal transport of glycoproteins in old rats, but the underlying mechanism is unknown. It is not known if the presence of abnormal tau protein in the hippocampus or other parts of the aged human brain plays any role in the delay of intraneuronal transport or in the dysfunctional cognition that occurs typically in older adults.

A second abnormal protein, βA, which is found in the core of senile plaques and in diffusely distributed extracellular collections, has been shown to be cytotoxic to cells *in vitro* under some conditions that are not fully defined. As it occurs in the aged brain in the extracellular space, often closely associated with blood vessels, it may interfere with the transport of ions, transmitter substances, and metabolites through synaptic clefts and the perineuronal extracellular space. It seems unlikely that the overexpression of amyloid precursor protein, from which abnormal βA protein is derived, results in the accumulation of βA in apparently normal older adults in small amounts, or in large amounts in Alzheimer's disease. It seems unlikely, also, that the formation of abnormal tau protein results from the overexpression of tau protein-related genes. The accumulation of both abnormal proteins in apparently normal old persons and in victims of Alzheimer's disease appears to be post-translational.

See also: Dementia; Models of Aging: Vertebrates; Neuroimaging (MRI, PET).

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Cancer and Age

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Glossary

Apoptosis – Cell death.

Growth Factors – Proteins that regulate the cell, functioning by binding to specific receptor molecules in the cell membrane and stimulating receptor-mediated activation of intracellular signal transduction pathways.

Incidence – Number of persons developing cancer in a unit of time divided by total population living at that time.

Intra-epithelial Neoplasia (also called dysplasia, atypical hyperplasia, atypical proliferation, and carcinoma in situ) – Lesions that predispose a person to develop cancer.

Oncogenes – Damaged versions of normal genes that control cell growth and differentiation.

Prevalence – Number of persons with a cancer at a given point in time divided by total population living at that time.

Introduction

Cancer is the second leading cause of mortality after heart disease and the leading cause of death among women ages 40 to 79 and men ages 60 to 79. Within the 65+ age group, the population 85 years and older is projected to double from 4.3 million in 2005 million by 2030. Life expectancy has increased. More people are treated successfully after a cancer diagnosis, resulting in a greater prevalence of the elderly living with or developing cancer. It is important for all professionals dealing with the elderly to understand what the disease is and how to deal with it. In the past, the elderly were denied treatment because they were considered 'too old.' We now know that in many instances the elderly do as well or better with cancer treatments than the young. This article reviews the causes and biology of cancer, possible ways of preventing it, clinical descriptions of some of the common cancers, how to screen for cancer, and new targeted treatment options.

Cancer may be defined by the four characteristics that describe how cancer cells behave differently from normal cells:

1. Cancer usually begins from a single cell that proliferates to form a clone of malignant cells.
2. Cancer cells grow autonomously, are not regulated by the normal controls, and do not die appropriately via programmed cell death (apoptosis).
3. Cancer cells do not differentiate in a normal coordinated manner and do not look the same as the normal cells surrounding them.
4. Cancer cells develop the capacity for discontinuous growth and spread to other parts of the body (metastasis).

Cancer is also called malignant neoplasm. This implies that the growth is a new growth (neoplasm) that if unchecked will kill the host (malignant). Normal cells can express some of the preceding properties at certain appropriate times, such as in wound healing, embryogenesis, organ repair and regeneration, and revascularization, but the proliferation is coordinated, orderly, and self-limited. In cancer, however, these characteristics are excessive, disordered, and not self-limited, resulting in an inappropriate proliferation (tumor burden) and spread that is inappropriate to the host and that has morbid implications if not successfully treated.

Cancer traditionally was classified as being either a carcinoma or a sarcoma named for the presumed cell of origin: epithelial (carcinoma) or mesenchymal (sarcoma). Recent evidence has demonstrated that most if not all neoplasms arise from immature stem cells that then differentiate along normal cell lines, but mutate and acquire the properties of autonomous growth as described previously. We now realize that carcinomas of the lung, breast, and stomach do not arise from well-differentiated 'normal' cells in these organs but

from stem cells that begin to differentiate in the direction of these tissues but then become autonomous and have impaired apoptosis. These cells lose their normal self-limiting capacity and acquire properties that allow them to enter the circulation and spread to other organs. These cancer cells are the 'seed,' and if other organ's 'soil' supports their growth, metastases grow distant to the primary site. Cancers of the lymphatic system or blood-forming cells are termed hematopoietic malignancies. Lymphoma, leukemia, and multiple myeloma are the most common of the hematopoietic malignancies. Thus, a neoplasm is usually named by what the cells resemble and where they arise. A cancer of the lung implies that the cells resemble lung cells and arise in that organ. An osteosarcoma resembles bone cells and is found in bone. Leukemia resembles white cells and is found in the bone marrow. It is still useful to classify cancer cells as a carcinoma, a sarcoma, or hematopoietic, as there are specific tumor markers (proteins on the cell surface) that are present on the tumor cells and that can be detected by the pathologist using different immunohistochemical staining techniques. The treatment depends on the cell of origin.

The traditional classification of neoplasms (new growths) divides them into benign and malignant types. These characteristics are determined by the predicted behavior of the tumor rather than by the microscopic morphology. The term malignant refers only to tumors that metastasize. Since there are some malignancies that are very slow-growing and late to metastasize, a new term is used to describe their propensity – borderline, intermediate, or undetermined.

Microscopic grading is another way of classifying tumors in an attempt to predict if the neoplasm is one that is slow growing, rarely metastasizes, and is highly curable, or if it is one that is fast growing, often metastasizes, and is rarely curable. The criteria used in microscopic grading include cellularity, pleomorphism, mitotic activity, type of margins, amount of matrix formation, and the presence of inflammation necroses and hemorrhage. Most often, the three-grade system is used: grade 1 (well-differentiated), grade 2 (moderately differentiated), and grade 3 (poorly differentiated or undifferentiated). The lower the grade, the more likely that the person with the tumor will survive. The stage of the tumor is used to determine the amount of spread; it is usually graded from I to IV. Stage I usually represents limited disease in one location, stages II and III indicates growth and spread specific to the organ system involved, and stage IV indicates spread to other organs. The prognosis usually depends upon stage and grade. Although stage and grade usually parallel each other, small high-grade tumors may be more dangerous to the host than larger lower-grade tumors.

Prediction of prognosis has been enhanced by the newer technology of gene chip arrays, which look at the molecular signature of tumors correlated with clinical data to predict prognosis. There have been several reports showing correlation of gene signatures with outcome. This may allow oncologists to design treatment based on the aggressivity of the tumor. For example, women with stage I breast cancer have a 70% chance of 5-year survival without adjuvant chemotherapy. This number increases to the 80th percentile with chemotherapy, but this also means that many women may not need adjuvant chemotherapy at all. As of mid-2005, there is no clear way to predict who does. Most women with tumors greater than 1 cm with a good performance status may be offered chemotherapy. There are multiple ongoing clinical trials to test the use of DNA chips to help determine therapies for lymph node-negative breast cancer patients and multiple other cancers. These will test whether genetic 'profiling' (a snapshot of a patient's genetic makeup with respect to relevant genes) is more effective than standard histopathological and clinical criteria in predicting which patients will develop metastatic disease.

Finally in terms of classification, there are some lesions that predispose the person to develop cancer, usually a carcinoma. Because cancer is a multistep process, what is seen microscopically are the various steps before a full-blown malignancy develops. These have been called dysplasia, atypical hyperplasia, atypical proliferation, and carcinoma *in situ*. Since these terms have been used in a confusing manner, it is probably safer to designate these lesions as intraepithelial neoplasia. Using this term plus a grading system to indicate varying degrees of severity probably is the most reasonable way to determine propensity to develop a full-blown malignancy and helps in directing therapy.

Epidemiology of Cancer

Cancer occurrence in a period of time for a given population is expressed in various ways (**Table 1**). The incidence rate is a direct measure of the probability of developing cancer and is usually expressed per year. Incidence rates may be crude (all ages) or age specific. Since cancer is very age dependent, age-specific rates are usually more informative. When comparing population groups with different age distributions (such as the United States vs. China), the incidence rate should be age adjusted by multiplying each age-specific rate by the percent of individuals in a population with the same ages and

Table 1 Measures of cancer frequency

Incidence	$\frac{\text{Number of persons developing cancer in a unit of time}}{\text{Total population living at that time}}$
Prevalence	$\frac{\text{Number of persons with a cancer at a given point in time}}{\text{Total population living at that time}}$
Mortality (death) rate	$\frac{\text{Number of persons dying of cancer in a unit of time}}{\text{Total population living at that time}}$
Case fatality rate	$\frac{\text{Number of deaths from cancer} \times 100\%}{\text{Number of persons developing cancer}}$

then summing these to produce a single value. For etiological studies, incidence rates tend to be more informative than mortality rates, as they identify all diagnosed cases.

In contrast, the prevalence rate is not usually used to study etiology, but is useful to plan health services, as it measures the burden of disease in the population. The mortality (death) rate gives us information as to which cancers are most lethal. Since this rate is derived from death certificates, it may often be inaccurate. However, it is useful to evaluate the impact of cancer prevention and treatment on the general population. The case fatality rate is a measure of the severity of the disease and is usually expressed as a percentage. This number is least useful in chronic cases, as it is expressed per unit of time. In chronic cases, it is more useful to express the survival rate per 5 or 10 years.

Patterns of Cancer Occurrence

Cancer is currently the number two killer, second only to heart disease, in the United States. It is responsible for over 22.8% of all deaths (2002 statistics). Cancer is the leading cause of death among women ages 40 to 79 and men ages 60 to 79. Cancer is mostly a geriatric illness: as the population ages, more and more people will be afflicted with and potentially die from this disease. Most epithelial cancers are rare under the age of 30, but the incidence rises with age. **Table 2** lists the major forms of cancer, the estimated number of new cases, and the case fatality rates. There are marked ethnic variations in cancer incidence as well as differences between men and women.

Table 3 shows the marked differences between men in age-adjusted incidence rates for men of selected cancer sites between Whites, Blacks, and Hispanics in the United States. In **Table 4**, similar data are shown for women. These differences suggest that there are genetic factors in the development of cancer; there are also differences in socioeconomic classes. Overall, the lower the socioeconomic class, the higher the cancer rate. This might reflect differences in the use of tobacco, nutritional status, and exposure to carcinogens. This may also explain some of the differences in Black to White to Hispanic cancer incidence.

Clusters of cancer have been found in various geographical regions and in people of similar occupations. These types of studies have been useful in identifying potential environmental risks. There are also striking international variations in incidence by geographical location that is associated

Table 2 Estimated number of new cases and case fatality rates of major cancers in the United States, 2005[a]

	Number of new cases	*Case fatality rate (%)*
All sites	1 372 910	41.5
Lung	172 570	94.8
Colon and rectum	145 290	38.7
Breast (excluding intraepithelial neoplasia)	212 930	19.2
Prostate	232 090	13.1
Urinary tract	101 880	26.1
Uterus (excluding cervical intraepithelial neoplasia)	51 250	21.5
Oral cavity and pharynx	29 370	24.9
Skin (excluding basal cell and squamous)	66 000	16.1
Pancreas	32 180	98.8
Leukemia	34 810	64.8
Ovary	22 220	73.0
All other sites	272 320	56.2

[a] NCI SEER Program.

Table 3 Average annual age-adjusted incidence rates per 100 000 people for common cancers by racial and ethnic groups for US males, 1997–2001[a]

	Incidence rates		
Type of cancer	*Whites*	*Blacks*	*Hispanics*
All sites	556.5	689.2	419.8
Lung	77.9	117.2	45.2
Colon and rectum	63.1	72.9	49.6
Prostate	167.4	271.3	140.0

[a] NCI SEER Program.

Table 4 Average annual age-adjusted incidence rates per 100 000 people for common cancers and racial and ethnic groups for US females, 1997–2001[a]

	Incidence rates		
Type of cancer	*Whites*	*Blacks*	*Hispanics*
All sites	429.8	400.1	309.9
Lung	51.3	54.5	23.9
Colon and rectum	45.9	56.5	32.5
Breast	141.7	119.9	89.6
Cervix	8.9	11.8	16.2

[a]NCI SEER Program.

with exposure to known risks in the environment, by lifestyle, or by genetic predisposition. For example, hepatocellular carcinoma is a common cancer in countries where hepatitis B is endemic, and transmission is often transplacental (mother to child) but rare in populations with low exposure. Prostate and colorectal cancer are common in developed countries and less common in developing countries. This phenomenon has been epidemiologically linked to high-fat, low-fiber diets.

Possible Causes of Cancer

The epidemiological approach has made it possible to identify lifestyles and other environmental exposures as causes of cancer.

Tobacco

Tobacco smoking is the number one risk identified to date. Smoking has long been linked to cancer of the lung, oropharynx, nasopharynx, larynx, esophagus, bladder, kidney, uterus, cervix, colon, pancreas, and leukemia. It is estimated that smoking cigarettes accounts for 40% of cancer deaths in men and 20% in women, with lung cancer being the most common type. For smokers of two or more packs per day, the risk of lung cancer is 20 times that of non-smokers. In addition, smokeless tobacco and passive exposure to smoking also increase the risk of developing cancer.

Alcohol

Consumption of alcohol potentiates the effect of smoking in cancers of the mouth, pharynx, esophagus, and larynx and is estimated to account for 3% of cancer deaths. Alcohol might also potentiate other carcinogens. In the most recent Surveillance, Epidemiology, and End Results (SEER) data there was a decrease in alcohol-related cancers in the United States. The effect of quitting alcohol and tobacco is a 70% reduction in esophageal cancer within 5–9 years.

Environmental Pollutants

The workplace also exposes people to various carcinogens, and it is estimated that 5% of all cancer deaths result from this exposure. Asbestos is the major occupational carcinogen, as it causes both lung cancer and the rarer mesotheliomas. Smoking is synergistic with asbestos, as smokers exposed to asbestos have a far greater chance of developing cancer than non-smokers. Other examples of occupational risks include benzene causing leukemia, radiation-induced cancers, aromatic amines causing bladder cancers, inorganic arsenic causing lung, skin, and liver angiosarcoma, and vinyl chloride causing angiosarcoma.

It has been difficult to ascertain how important environmental pollution is in causing cancer. It is thought that it is relatively uncommon and that only 2% of cancer deaths are caused by environmental pollution. Certainly smokers are at greater risk of developing cancer than non-smokers exposed to the same atmosphere. Some of the risks identified include asbestos, airborne arsenic, cooking oil vapors in wok cooking in China, and effluents from coal heating stoves.

Radiation

Ionizing radiation is another well-studied carcinogen. It has long been known that radiologists, survivors of the atomic bomb in Japan, and patients receiving radiation therapy are at increased risk of developing cancer. Nearly all the sites of the body are vulnerable to radiation, with the most sensitive being bone marrow, breast, and thyroid. It is not clear how much, if any, risk comes from diagnostic X-rays or background atmospheric radiation over long periods of time.

Ultraviolet radiation from the sun is the major risk factor for all skin cancers (squamous cell, basal cell, and melanoma). Skin cancers usually develop on sun-exposed areas and are more common in outdoor workers and fair-skinned individuals. Very high rates of skin cancers occur in people who have genetic illnesses exacerbated by sunlight (xeroderma pigmentosum and albinism). The offending UV radiation appears to be in the UV-B spectral range (290–320 nm). It is believed that depletion of the ozone layer has led to greater amounts of UV-B radiation reaching the earth's surface.

Medications

It is estimated that about 2% of cancers arise from exposure to pharmaceutical medications. There is evidence that conjugated estrogens taken after

menopause increase risk of developing endometrial cancer of the uterus and possibly breast cancer. Estrogens have also been implicated in causing vaginal and cervical cancer in daughters of women treated with this hormone during pregnancy. The combination of estrogens and progesterone in postmenopausal women seems to decrease the risk of cancer of the uterus when compared to unopposed estrogen therapy.

Other medications causing cancer include alkylating agents inducing non-lymphocytic leukemia and immunosuppression drugs causing non-Hodgkin's lymphoma.

Drugs are not always a negative; there is evidence suggesting that non-steroidal anti-inflammatory agents and aspirin protect against cancer of the colon.

Viruses

Viruses have been implicated in causing some cancers throughout the world. In the United States, it is estimated that 5% of all cancers are related to viruses. Epstein-Barr virus (EBV) probably causes endemic Burkitt's lymphoma in Africa and nasopharyngeal carcinoma in China. Hepatitis B virus (HBV) in Asia and China is associated with hepatocellular carcinoma; human T-lymphotropic virus type I (HTLV-1) is linked to adult T-cell leukemia in Japan and the Caribbean. Human immunodeficiency virus (HIV), which causes AIDS, is associated with lymphoma. Kaposi's sarcoma in homosexual men is probably related to both HIV and herpes simplex virus 8 (HSV8). Human papillomavirus is associated with cancer of the cervix, anus, vulva, vagina, and some cancers of the oropharynx and is sexually transmitted. Other potential virus-induced cancers include childhood leukemia and Hodgkin's disease (possibly EBV).

Diet and Nutrition

While diet and nutrition seem to be a very important factor in the high incidence of cancer in Western countries, the specific dietary components that either cause or protect against cancer remain unknown. High dietary fat intakes have been implicated as risk factors in colon and breast cancer. High-fiber diets seem to protect against cancer of the colon. Vitamins and other micronutrients may also be protective, such as carotenoids against cancer of the lung, vitamin C against gastric cancer, indole compounds in cruciferous vegetables against colon cancer, allyl sulfide in onions and garlic against gastric cancer, vitamin D and calcium against colon and breast cancer, and selenium and vitamin E against gastric cancer. In addition, certain dietary factors may cause cancer. For example, aflatoxin (a metabolite of the fungus *Aspergillus flavius*) contaminating foods such as peanuts is linked to liver cancer, salted foods are related to gastric cancer, and nitrosamine is linked to nasopharyngeal carcinoma.

Genetic Susceptibility

Genetic factors seem to play some role in the development of cancer, but it has been difficult to determine how much is due to genes as opposed to environmental and ethnic differences. For example, nasopharyngeal cancer in Chinese could result from a genetic predisposition, EBV virus exposure on a particular genetic background, or a propensity to eating salted fish with high nitrosamine levels. In any event, genetic factors are very important in skin cancer. The darker the skin, the less likely one is to develop skin cancer. An example of how complicated this area is may be seen by looking at cancer of the lung. Most smokers do not develop lung cancer, but if a person has the genetic makeup to rapidly oxidize certain drugs, the risk of developing smoking-related cancer of the lung is much higher. This could be the result of metabolizing various compounds to active carcinogens.

There are more than 200 single-gene disorders linked to neoplasia. These make up a very small fraction of cancers associated with rare syndromes. Genetic testing may be offered to the patient with cancer and their families in cases in which a well-defined inherited cancer syndrome may exist and early screening or other medical intervention may be useful. When syndromes such as familial adenomatous polyposis (FAP), multiple endocrine neoplasia (MEN), retinoblastoma, von Hippel-Lindau (VHL), hereditary breast/ovarian cancer syndrome (BRCA1, BRCA2 mutations), hereditary non-polyposis coli syndrome (HNPCC), and Li-Fraumeni syndrome are suspected, patients should be referred to a genetic counselor. Although cancers tend to occur early in most of these syndromes, elderly patients in the proper clinical setting should be screened, as this information is useful for other family members to plan early screening to prevent development of malignancy. It is necessary to test the proband (individual with the disease) as there may be specific mutations associated with these syndromes in different families or ethnic groups, but there may also be polymorphisms (a common variation; a non-deleterious mutation in DNA).

Principles of Carcinogenesis

The classical view of carcinogenesis was that it was a two-'hit' process – initiation (genetic) and promotion

(epigenetic). However, this is too simplistic and it is now realized that there may be six or more independent genetic mutational events. The newer theory of carcinogenesis is that it is a multistage process driven by both genetic damage (initiation) and other cellular changes (promotion). Tumor initiation begins in cells through genetic mutations that may be caused by chemical carcinogens, viruses, and physical agents. These mutated cells respond differently to their environment and have a selective growth advantage. The newly initiated tumor may be less responsive to negative growth factors, terminal cell differentiation, or programmed cell death (apoptosis). The initiated tumor cells will grow (or expand; 'clonal expansion') if there is physical disruption of the cells' normal microenvironment outside of genetic damage. This stage, promotion, also occurs from chemicals, viruses, and physical agents and results in further selective clonal expansion and proliferation of the initiated cells. The tumor promotion stage, while resulting in proliferation, will also cause further genetic mutation either by increasing cell proliferation or by the nature of the promoting agent (virus, chemical, physical) itself.

As the cells continue to proliferate with repeated genetic changes such as activation of proto-oncogenes, inactivation of tumor suppressor genes, and inactivation of antimetastatic genes, the tumor will transform into a malignancy. This multistage theory of carcinogenesis helps explain why the elderly are so susceptible to cancer. Time is an important element in carcinogenesis, as it takes multiple 'hits' to change a cell into a malignancy. The hits are both genetic and epigenetic, which explains why one may also need multiple risk factors. Thus, the elderly person has been exposed for years to various potential chemical, physical, and viral carcinogens.

Cancer Prevention

Diet and Exercise

Animal studies support a cancer-promoting role for fat, and in humans, epidemiological data strongly suggest that dietary fat intake may be associated with incidence and mortality of cancers of the breast, colon, rectum, and prostate. There are also data implicating fat in cancers of the ovaries, uterus, pancreas, and lung, but the evidence is not as strong. There is still a debate as to whether it is total dietary fat, specific fats, or total calories that are involved in carcinogenesis. In any event, cancers of breast, colon, and prostate are highest in North America and western Europe and lowest in Asia, and are directly related to the intake of total fat in the diet even when adjusted for total calories.

Increased saturated fat intake is associated with an increased incidence of breast, colon, and prostate cancer. High total polyunsaturated fats seem to increase the incidence of breast and prostate cancer. High fiber intake reduces cancer incidence, particularly for colon cancer. In countries where there is a high olive oil intake (a monounsaturated fat), breast cancer is less prevalent. Certain fats, such as the longer chain, highly polyunsaturated omega-3 fatty acids, such as those found in fish, offer protection against cancer. For example, Inuit who consume large amounts of fat from fish are at low risk of developing cancer, including breast cancer.

Migrant group studies show that as the migrants' diet switches to one more typical of the new country in terms of fat intake, the cancer rate also increases to that of the new country. For example, major increases in breast, prostate, and endometrial cancer incidence occurred among four immigrant groups in Hawaii – Chinese, Japanese, Filipinos, and Whites. When studies were done over time in Japan, it was found that from 1957 to 1973 the fat in the diet doubled, as did the total number of breast cancer deaths.

High fat intake also seems to be associated with colorectal cancer. Most studies support the role of saturated fat in carcinogenesis rather than polyunsaturated fat or monounsaturated fats. There have been other studies that implicate high beef and other animal protein intake.

In other cancers, such as prostate, ovary, pancreas, and lung, there may also be a connection with fat. However, studies on this possible connection had methodological problems and are far from conclusive. Most experimental animal studies have suggested that dietary fat acts as a cancer promoter, but there is also some evidence that it may be an initiator as well. It may be that fat acts by changing cell membrane characteristics or by changing the neuroendocrine system. With cancer of the colon, it has been postulated that fat influences the metabolic activity of fecal microflora and the concentration of sterol substrates in the colon. As a consequence, secondary bile acids, which are carcinogens, form in the colon.

The problem with the fat hypothesis is that the dangers of fat may result from childhood eating patterns. Similarly, it is not clear whether modification of the diet in adulthood or in the later years is of benefit. Furthermore, it is difficult to separate dietary fat from calories. Diets high in fat tend to be associated with obesity. The syndrome of insulin resistance in obese individuals raises

circulating insulin levels that may directly cause susceptible tissues to give a growth signal or may act through induction of potent growth factors such as insulin-like growth factor 1 (IGF-1). Obesity could conceivably be the risk for breast and endometrial cancer by raising estrogen levels through peripheral conversion by aromatase inhibitors. Caloric intake is inversely related to physical activity, and obese people usually do not exercise as much. Regular exercise appears to lower the risk for cancer, particularly breast, colon, and ovarian cancer. Studies have shown that even when breast cancer has occurred, women have a lower recurrence rate and live longer if they adopt a low-fat diet and exercise.

Fiber

A diet low in dietary fiber is associated with high cancer rates. Burkitt was the first to suggest that the low rate of colon cancer in Africa resulted from high fiber intake and large stool bulk. Non-starch polysaccharides, as found in fruits and vegetables, are the type of fiber that seems to correlate best with low cancer incidence.

Micronutrients

Since fruits and vegetables are high in micronutrients, it may be that it is not just fiber but also these micronutrients that protect against cancer. Cancer of the lung seems to be lower in populations that have a high beta carotene intake; other carotenoids may also be involved. Vitamin C may protect against certain cancers such as gastric cancer by blocking formulation of nitrosamines. Indole compounds found in cruciferous vegetables may decrease colon cancer, and allyl sulfide in garlic and onions may lower the risk of gastric cancer. It has been suggested that high calcium and vitamin D intake protect against colon and breast cancer. Selenium appears to protect against gastric, esophageal, and prostate carcinomas. Vitamin E and folic acid also may play roles in protecting against cancer. One cautionary note is that although a diet high in fruits and vegetables may be beneficial, it is not clear whether supplements give the same benefit. In a large Finnish placebo controlled trial looking at the effect of daily supplementation with vitamin E, beta carotene, both, or placebo on the incidence of cancer development in smokers showed no risk reduction with vitamin E and, unexpectedly, a higher incidence of lung cancer in those receiving beta carotene. The SELECT trial (Selenium and Vitamin E Cancer Prevention Trial) is a research study currently accruing patients to determine if selenium and vitamin E can help prevent prostate cancer.

There are also concerns that various food additives and contaminants are carcinogenic.

Exogenous Hormones

Taking exogenous hormones may increase the incidence of certain cancers. Estrogens have been implicated in uterine cancer and possibly in breast and ovary cancer. Testosterone is involved in cancer of the prostate. Certainly in people taking hormonal replacement, screening procedures for the cancers are essential.

Alcohol

High alcohol intake is associated with cancers of the oral cavity, pharynx, esophagus, and larynx, particularly in people who smoke. A smaller risk seems to exist between alcohol and liver, rectal, pancreatic, and breast cancers. A safe recommendation is to limit the intake of alcohol to moderate amounts such as one to two drinks per day.

Tobacco

Tobacco smoking is the most modifiable carcinogenic risk. Smoking is firmly linked to cancer of the lung, larynx, mouth, pharynx, esophagus, bladder, and pancreas. It also seems that smokers are more likely to develop cancer of the kidney, cervix, nose, stomach, and leukemia. The anti-smoking campaign in the United States and other countries is directly aimed at this problem.

Cancer prevention, in summary, currently emphasizes cessation of smoking, limiting alcohol intake, modifying diet to include avoidance of obesity, decreasing fat intake, increasing fiber, particularly fruits and vegetables (to a minimum of eight servings a day), consumption of whole grains, and avoidance of food additives and contaminants. Whether or not additional micronutrients should be added to our diet is being studied. Regular exercise during most days of the week for at least 30 min is also recommended.

Molecular Biology of Cancer

Gene Regulation

The sequencing of the human genome was begun in 1990 and completed in 2003. The International Human Genome Sequencing Consortium (2004) reduced the estimated number of human protein-coding genes from 35 000 to only 20 000–25 000. Each cell in the body contains the same genetic material, but only a few genes are expressed in each cell, which determines its phenotype. A gene consists of deoxyribonucleic acid (DNA). The gene will

transcribe a ribonucleic acid (RNA). In the nucleolus the RNA transcribed is ribosomal RNA (rRNA), and in the nucleoplasm the RNA transcribed is messenger RNA (mRNA) and transfer RNA (tRNA). The DNA gene acts as a template to form RNA.

Through a process called translation the cell forms protein. In this process, mRNA serves as the information source, and ribosomes move along the mRNA, adding amino acids carried by specific tRNAs to the growing peptide. At the end of this process, the newly formed protein is released and undergoes post-translational modifications necessary for function of the protein. Both transcription and translation are exquisitely controlled by a large array of cellular factors, which in turn are products of gene regulation, transcription, and translation. These factors regulate gene expression and ultimately determine what the cell will manufacture, how it will grow and function, and how long it will live. If these controls are disturbed, the cell will not grow and differentiate normally; the ultimate disarray is cancer.

Spontaneous human cancers arise from a series of somatic genetic cellular changes caused by abnormal deletions, rearrangements, amplifications, or point mutations. These DNA changes result in failure to regulate transcription and thereby disorder translation. The cell, therefore, becomes cancerous.

Oncogenes

Oncogenes are damaged versions of normal genes ('proto-oncogenes') that control cell growth and differentiation. It is important to realize that a proto-oncogene is a normal gene; it is only through pathological processes that it becomes an oncogene. Cancer is a multistep process in which multiple genetic alterations must occur, usually over many years. Thus, only after a long span of time will cell differentiation, division, and growth be changed. In human cancers, inherited mutations are relatively rare. Most oncogenes are acquired in the form of chromosomal translocations, deletions, amplifications, inversion, or point mutations. Oncogenes may act as transformers of cells and therefore act as positive regulators of growth. Oncogenes may also arise from normal genes that suppress tumor growth (recessive oncogenes). In this situation, the alteration results in lack of uncontrolled cell division and growth.

Oncogenes have been identified by studying transforming retroviruses and common sites of retroviral insertion, study of the transforming genes in DNA tumor viruses, DNA-mediated gene transfer in cell culture, identification of genes at translocation breakpoints in human cancer, and isolation of tumor suppression genes in chromosomal deletions.

Tumor suppression genes (anti-oncogenes), particularly the p53 gene, play a central role in tumor formation. p53 is located on chromosome p17, and alterations of this gene locus are found in a large percentage and wide variety of tumors. Change in p53 is the most common alteration in human cancer. Normal p53 gene activity seems to suppress tumor growth, and inactivation of its activity (such as by viruses) allows uncontrolled division and growth.

Work has shown that most of the genes whose alterations or deregulation lead to cancer are involved in cell division and the control of the cell division by signal transduction. To achieve coordinated growth, differentiation, and adaptation, cells must have complex pathways from the outside of the cell to the inside. These pathways initiate and amplify signals (signal transduction) from outside the cell to specific targets within the cell, such as the nucleus and cytoskeleton. These signals start at the extracellular cell membrane, where all surface receptors interact with ligands (growth factors) that are soluble or are on other nearby cells. Growth factors, therefore, initiate the signal that tells the cells to proliferate and grow by entering the cell cycle.

Apoptosis and Cancer

Much of cell death is genetically programmed by the process called apoptosis. In apoptosis, when the cell is damaged, the DNA initiates cell destruction, or suicide, and the cell is slowly broken into small packages that are removed by phagocytic cells, and there is no inflammation. In cancer, not only does proliferation occur, but apoptosis is blocked, resulting in accumulation of abnormal cells.

Scientists are beginning to investigate mechanisms of restoring and inducing apoptosis in cancer cells. Several approaches are being sought; one is to introduce apoptosis signals, allowing the cancer cells to die while rescuing the normal cells. Another is to reintroduce into the cancer a normal gene involved in setting off apoptosis, such as the normal p53 gene; a third method is to shut off proliferation genes (such as mutated Ras), which by itself inhibits apoptosis. If the mutated Ras gene is shut down, apoptosis will start up again and cancer cells will die.

Cancer Metastases

Cancer kills people because the tumor both invades and metastasizes. Approximately 30% of patients newly diagnosed with a cancer have detectable metastatic disease. About another 30% have occult

metastases (micrometastases) that will become evident in time. Thus, 60% of cancer patients will have multiple dormant metastases and will ultimately fail therapy and die of the cancer. The formation of metastases begins early in the growth of the primary tumor and increases with time. Small metastases up to 1 mm in size receive nutrition by diffusion but need to have new blood vessels (neovascularization) to grow larger. There has been a long search for the angiogenic 'switch.' Some target molecules and new therapies are being developed to thwart this neovascularization.

Cancers can have very different metastatic potential that depends upon their histologic type and intrinsic aggressiveness. It appears that metastasis occurs soon after the primary tumor vascularizes. Metastasis is a process separate from tumor formation. The genetic changes that lead to tumor formation do not by themselves cause erosion and metastases (see **Table 5**). Invasion involves substances such as proteases, adhesion receptors, and motility cytokines. Metastases also involve these.

Table 5 Progression of cancer and the positive and negative influences on its growth and spread[a]

	Growth	*Spread*
Positive influences	Activated oncogenes	Proteases
	Growth factors (cytokines)	Adhesion receptors
		Motility cytokines
		Angiogenesis
Result	Uncontrolled proliferation	Invasion and metastases
Negative influences	Tumor suppression genes	Metastatic suppression genes
	Growth inhibitors	Protease inhibitors
		Immunologic rejection
		Proteosome inhibitors
Result	Decreased or no growth	No invasion or metastases

[a] NCI SEER Program.

The Cell Cycle

In every population of cells there are three types of cell. The first group consists of cycling cells, which continuously proliferate by going from one mitosis to the next. The second is composed of terminally divided cells, which will die without ever dividing again. In the third group the cells are not dividing, but can re-enter the cell cycle if the appropriate stimulus is supplied. This phase is termed G0.

The cell cycle itself has four different phases: G1, S, G2, and M (**Table 6**). For a cell to go from G0 to G1, multiple genes must be expressed (i.e., C-MYC and C-FOS). Then during G1, as the cell begins to grow, in order to progress other genes are activated (e.g., ornithine decarboxylase, C-MYB). The critical point in G1 is called the restriction point; to pass through this, IGF-1 and the GFI receptor gene must be activated. G1 cyclins are also produced either before or after IGF-1; these proteins are necessary to allow the cell to carry on DNA synthesis or enter the S phase. During the S phase, all of the DNA synthesis genes are activated, including the DNA polymerases. Tumor suppression genes (anti-oncogenes) such as p53 seem to work at this step, either before DNA synthetic genes are activated or between appearance of the IGF-1 receptor and the transcription of the DNA synthesis genes. After the chromosomes are replicated, the cell enters the G2 phase, when the genes necessary for mitosis (or meioses) are activated. During this phase, products such as $P34^{cdc2}$, cyclins A and B, and C-Mos are produced. The cell then enters the M phase and the cell divides. All of the genes that are activated during the cell cycle are proto-oncogenes. Mutations in these genes can lead to abnormal growth; they would then be termed oncogenes. The suppressor factors are then the anti-oncogenes. In addition, genes coding for growth factors (cytokines) are also proto-oncogenes, and their mutations are oncogenes.

Table 6 The cell cycle and associated production of selected gene products

Phase of cell cycle	*Activity of cell*	*Examples of genes activated*
G0	Resting	As enters G1
		C-MYC and C-FOS and others
G1	Growth to prepare for DNA synthesis	Ornithine decarboxylase
		C-MYB
		Insulin-like growth factor 1 (IGF-1)
		IGF-1 receptor
		G1 cyclins
S	DNA synthesis	DNA polymerases
	Chromosomal duplication	All other DNA synthesis genes
G2	Growth to prepare for mitosis (or meiosis)	$P34^{cdc2}$
		Cyclins A and B
		C-MOS
M	Mitosis or meiosis	

Growth Factors (Cytokines)

Growth factors are proteins that regulate the cell; they function by binding to specific receptor

molecules in the cell membranes and thereby stimulating receptor-mediated activation of intracellular signal transduction pathways. These pathways are activated beginning with stimulation of tyrosine kinase to phosphorylate other proteins. These are both stimulatory and inhibitory growth factors.

Many oncogenes are analogues of cellular proto-oncogene that code for growth factors, their receptors, or pathways mediated by tyrosine kinase activation. Some viral oncogenes have been shown to be derived from animal cell proto-oncogene and work via these growth factor and receptor pathways. Expression of viral oncogenes is sufficient to induce malignant transformation in certain cells. Many other oncogenes have been found that apparently are not viral in origin that work at these sites of growth factors and receptors and signal transduction.

Chromosome Abnormalities

Cancer is often associated with specific chromosomal abnormalities. Many of the genes involved in consistent chromosomal rearrangements have been identified. Some of the resultant alterations in gene structure and function have been found. It is clear that as a rule, multiple genetic changes are usually required to transform a cell from its normal state to a malignant one. The simplest chromosomal change is a gain or loss of a whole chromosome. Structural changes are translocations (exchange of material between two or more chromosomes), deletions (loss of DNA from a chromosome), and inversions (a single chromosome is broken in two places and the central portion is inverted). Translocations are the most common chromosomal abnormalities found in human cancer, but some deletions have also been described. In some cancers, the chromosome appears normal, but there is extra genetic material (amplification) or a point mutation.

Many proto-oncogene are located in the chromosomal bands that are involved in consistent translocations. Because of the translocation, the proto-oncogene is either not in the right place or is altered so that it functions as an oncogene.

Chromosomal analysis helps us to define the type of malignancy, as specific cancers have specific chromosomal abnormalities. It is hoped that in the future we will be able to type a tumor to make a genetic diagnosis and direct therapy toward the specific genetic defect. With the new gene chip, automated analysis of many genes is possible; this technique holds promise.

Molecular Markers

Molecular biological tests will be available to identify the genetic and cellular alterations of each specific cancer by about 2015. Multiple tumor suppressor genes, oncogenes, genetic translocations, deletions, and amplifications have been described. Some genetic alterations are found on gene chips as 'signatures.' A signature is a particular clustering of genes. Many of the genes found in these clusters control proteolysis, angiogenesis, cell adhesion molecules, and hormone receptors, but not all have a known function. It may be the interplay of multiple gene products that gives the resultant behavior characteristics. Further complicating the delicate interplay in the cell are epigenetics, which are heritable changes in gene function that occur without a change in the DNA sequence. Multiple epigenetic mechanisms such as DNA methylation, histone acetylation, and RNA interference have effects on gene activation and inactivation. These mechanisms are also areas being studied for possible therapeutic intervention. A histone deacetylase inhibitor, desipeptide, is in cancer clinical trials in humans.

We do not have complete knowledge as to how age affects tumor growth or spread. We also have little knowledge of proteogenomics, which looks at the effects of drugs on the molecular machinery of cells and the effect of age.

Common Cancers in the Elderly

Lung Cancer

Lung cancer is the leading cause of death in the United States for both men and women. It accounts for 31% of male and 27% of female cancer deaths. Half of all lung cancers occurs in people age 65 and older. At age 50 in men, the incidence of cancer is 100/100 000, while at age 70 it is 500/100 000. For smokers, the risk of lung cancer continues to rise with increasing age. However, for men over 80 and women over 75, the incidence of lung cancers decreases in the general population, reflecting lower smoking prevalence.

Cigarette smoking causes 80–90% of all lung cancer. There is a direct relationship between the total number of cigarettes smoked in a lifetime and development of cancer. In addition, passive exposure to cigarette smoke is a risk. The positive aspect of this is that it is never too late to stop smoking. Elderly people who stop smoking will have a lung cancer risk reduction to a degree as high as in young people. It is pivotal for health-care workers to advise all people to stop smoking.

Tobacco smoke contains at least 20 carcinogens that can act as either initiators or promoters of cancer. Asbestos exposure increases the risk of cancer 3- to 5-fold in non-smokers and 80- to 90-fold in

smokers. A family history of lung cancer also raises the risk of developing lung cancer about 2.5-fold. There are also numerous other substances such as nickel, chromium, arsenic, polyvinyl chloride, isopropyl oil, and various hydrocarbons that have weaker causal links to lung cancer. Ionizing radiation, particularly in miners, acts synergistically with cigarette smoking.

There are four main subtypes of lung cancer: squamous cell, small cell, adenocarcinoma, and large cell. Small cell lung carcinoma (SCLC) is the most lethal and aggressive of all lung cancers, and often the others are described collectively as non-small cell lung carcinoma (NSCLC). Most lung cancers are linked to cigarette smoking. However, the risk of SCLC and squamous cell is 20–25 times greater in smokers than in non-smokers. The risk of adenocarcinoma and large cell is about three times greater in smokers.

SCLC arises from primitive basal epithelial cells of neuroectodermal origin, the Kulchitsky cells. One characteristic of this type of cancer cell is that it sometimes secretes peptide hormones such as adrenocorticotropic hormone (ACTH) or antidiuretic hormone (ADH). The cell of origin progresses through metaplasia, atypia, and, finally, carcinoma. The cancer grows as a submucosal infiltrate and often causes extrinsic airway compressions with postobstructive pneumonia. SCLC grows rapidly, metastasizes early, and is rarely surgically curable. It is the lung cancer that most commonly causes superior vena canal syndrome and recurrent laryngeal nerve paralysis (hoarseness).

Squamous cell lung cancer is also highly linked to cigarette smoking. This type of cancer arises from respiratory epithelial injury with replacement of columnar epithelial cells with metaplastic squamous epithelium. The process continues with progression through atypia to carcinoma. It arises in large central airways and often presents with cough, hemoptysis (coughing of blood), and postobstructive pneumonia. This is the slowest growing of the lung cancers and is the most likely to be surgically curable.

Adenocarcinoma and large-cell lung cancers typically present in peripheral locations outside of the airways. Adenocarcinoma is associated with preexisting lung scars. Bronchoalveolar carcinoma is an uncommon variant of adenocarcinoma and is not linked to cigarette smoking. It has the best prognosis of all lung cancers. Both adenocarcinoma and large-cell have a much better prognosis than SCLC.

With increasing age, the relative proportion of squamous cell cancer increases while that of adenocarcinoma decreases. In people under 55, about 30% of lung cancers are squamous cell, while in those over age 70, close to 50% are. This implies that surgical cure rates would potentially be greater in elderly people.

Lung cancer is usually symptomatic at the time of diagnosis. It may present as cough, wheezing, chest pain, shortness of breath, pneumonia, or coughing-up of blood. Many patients with lung cancer will have systemic symptoms such as loss of appetite, weight loss, fatigue, and weakness. In SCLC, patients can have sodium problems due to increased ADH secretion by the tumor or Cushing's syndrome from ACTH secretion. When there are metastases, the patient can have a wide variety of symptoms referable to where the tumor is, such as bone pain, abdominal pain, or confusion. It is important in older people to investigate these non-specific symptoms and not just attribute them to 'old age' or to comorbid conditions. New targeted therapies have been developed including monoclonal antibodies against vascular endothelial growth factor (VEGF) and epidermal growth factor receptor (EGFR).

Colorectal Cancer

Colorectal cancer is the third most common malignancy in the United States. This cancer occurs mainly in older people; only about 10% is found in people younger than 50. Age is the leading risk factor for colorectal cancer, and risk doubles each decade after age 50 until age 80.

A major risk factor is the presence of colonic adenomatous polyps. About 5% of adenomas become malignant, with villous adenomas being more likely than tubular adenomas to turn malignant. The larger the adenoma (more than 1 cm), the more likely it is to become cancerous. Also, the more polyps that are present, the more likely there is to be cancer. If there is one cancer of the colon, there is a greater likelihood of developing a second. Patients with familial polyposis are at greater risk of developing colorectal cancer.

Inflammatory bowel disease also predisposes one to cancer of the colon. About 3–5% of patients with ulcerative colitis will develop cancer. The risk of developing cancer increases with duration of the disease and the extent of bowel involvements. Granulomatous colitis also carries an increased risk of cancer, even though the risk is less than with ulcerative colitis.

Lifestyle is very important in the development of colorectal cancer. A high-fiber, low-fat diet seems to be protective. Beer drinking and sedentary lifestyles have been also suggested as possible risk factors. Strangely enough, cigarette smoking seems to be protective.

Most colorectal cancers can be classified as one of five morphological types: adenocarcinoma, mucinous (colloid) adenocarcinoma, signet-ring

Table 7 Clinical stages of colorectal cancer[a]

Stage	*Characteristics*
Stage 0 (Duke's A colon cancer)	Cancer is found only in the innermost lining of the colon (carcinoma *in situ*)
Stage I (Duke's B colon cancer)	Cancer has spread beyond the innermost tissue layer of the colon wall to the middle layers
Stage II (Duke's C colon cancer)	Stage IIA: Cancer has spread beyond the middle tissue layers of the colon wall or has spread to nearby tissues around the colon or rectum. Stage IIB: Cancer has spread beyond the colon wall into nearby organs and/or through the peritoneum
Stage III (Duke's C colon cancer)	Stage IIIA: Cancer has spread from the innermost tissue layer of the colon wall to the middle layers and has spread to as many as three lymph nodes Stage IIIB: Cancer has spread to as many as three nearby lymph nodes and has spread: ● beyond the middle tissue layers of the colon wall, or ● to nearby tissues around the colon or rectum, or ● beyond the colon wall into nearby organs and/or through the peritoneum Stage IIIC: Cancer has spread to four or more nearby lymph nodes and has spread: ● to or beyond the middle tissue layers of the colon wall, or ● to nearby tissues around the colon or rectum, or ● to nearby organs and/or through the peritoneum
Stage IV (Duke's D colon cancer)	Cancer has spread to other parts of the body, such as the liver or lungs

[a] Adapted from http://www.cancer.gov. Duke's staging system has been largely replaced by TNM staging. T (tumor), N (nodes), and M (metastases) staging systems for all cancers are available through the American Joint Committee on Cancer (AJCC).

adenocarcinoma, scirrhous, and carcinoma simplex. The more differentiated the tumor is histologically, the better the prognosis.

Anatomic staging has been very useful in carcinoma of the large bowel, as this is a late metastasizing tumor. The TNM (tumor size, nodal status, presence of metastases) staging system is the one most commonly used and translated into clinical stages (**Table 7**). This system prognosticates how the patient is likely to do. Age does not affect prognosis, nor does it affect treatment outcomes. Thus, in older people it seems important to screen for cancer of the colon with digital rectal exams, checking the stools for blood, and, in patients with family histories of blood in the stool or a history of polyps, examination of the colon. It is not yet definitively clear what combination of screening tests should be used. Unfortunately, virtual colonoscopy using computed tomography (CT; computerized X-ray images) and sigmoidoscopy (which looks at only the left side of the colon) miss many lesions. The incidence of right-side colonic lesions is increasing, so colonoscopy every 10 years beginning at age 50 may be the best screening tool, albeit very expensive and labor intensive.

Prompt recognition of cancer of the colon is very important. If the cancer is in the left side of the colon, it will present with crampy abdominal pain, signs of obstruction, or bleeding. Rectal cancers bleed, and the patient complains of constipation, a sense of incomplete evacuation, and urgency. Cancers of the right side of the colon can present with abdominal pain, but often present as iron deficiency anemia (weakness). This has led many centers to use a complete blood test and serum ferritin as screening tests in the elderly and to examine the colon with barium enema and sigmoidoscopy or colonoscopy in all patients with iron deficiency.

Breast Cancer

Breast cancer is the most common invasive malignancy in women and increases in incidence with advancing age. Over 50 000 women over 65 years of age are diagnosed annually in the United Stated out of 180 000 new cases of breast cancer. The incidence of invasive breast cancer has leveled off and appears to be decreasing, probably secondary to screening and treatment of earlier lesions.

Breast cancer is characterized by a long duration and a marked heterogeneity among and within patients. In general, breast cancer is one of the slower-growing tumors, with a long preclinical (nondetectable) phase. Even when the cancer is apparent and metastasized, the life span of the patient may be for many years. In spite of this, some patients have a more aggressive form of the disease and die rapidly. As a general rule, older patients have more estrogen receptors (better-differentiated tumors) and fewer cells in the S phase of growth or slower growth. These factors should indicate a better prognosis, but elderly women often present with more extensive disease and metastases. Thus, one cannot prognosticate in an individual patient on the basis of age alone. Overall, histologic type, location, and stage are the same at all ages.

A unifying hypothesis to explain breast cancer with age is the theory that most breast cancers arise in the premenstrual period, when the breast is proliferating under the cyclic influences of gonadotropins, estrogen, progesterone, and prolactin. It is

during this period that the initiation and promotion of neoplasia are likely to occur. Since overall most breast cancer grows slowly, it will take many years to show up, and will do so in the postmenopausal years. The better-differentiated tumors (estrogen and progesterone receptor positive) have fewer cells in the S phase, will take many years to grow, and are the ones that will show up in older ages. Conversely, the faster-growing tumors will become clinically apparent in the premenopausal years.

The risk of a woman in the United States developing breast cancer during her lifetime is 11%; 3–4% will die from this disease. Overall, 70% of breast cancer patients do not have any identifiable risks. The risk factors that have been implicated include family history, early menarche, late menopause, not having children, first pregnancy over the age of 30, possibly high-fat diet and high alcohol intake, sedentary lifestyle, and exposure to ionizing radiation.

Multiple mutations on chromosome 19 (BRCA) have been identified in families with breast and ovarian cancer. This accounts only for 10–20% of breast cancer cases.

The role of hormonal use is still not clear. In both young women taking oral contraceptives and postmenopausal women taking estrogens, there may be a very slight increased risk of developing breast cancer. However, this is not definitive, and in any event it seems to be a very small risk, if existent at all.

Breast cancer is classified histologically as either ductal or lobular, corresponding to the ducts and lobules of the normal breast. It is believed in spite of this that most tumors arise in the terminal duct sections of the breast. Breast cancer can present as an intraepithelial neoplasm (carcinoma *in situ*) and is either lobular or ductal. Of the invasive carcinomas, about 75% are ductal, 10% lobular, 9% medullary, and 3% minimally invasive ductal; the remainder are a variety of histological types. Lobular tumors tend to be multicentric and bilateral. A poor prognostic finding is inflammatory breast cancer in which tumor cells block lymphatic channels in the breast. Paget's disease refers to a neoplastic eczemoid change of the nipple. Its prognosis is determined by the underlying neoplasm.

Non-invasive carcinomas are almost always cured by mastectomy, as they rarely metastasize. Ductal carcinoma *in situ* can be palpable but is more likely to be found by mammography as microcalcifications. It is often unilateral and unifocal but occasionally can be extensive throughout the breast. It is usually found in older women. In contrast, lobular carcinoma *in situ* is invisible on mammography, as it does not calcify, is usually multicentric and often bilateral, and is found in younger women.

Clinical staging is based upon the size and extension of the tumor, spread to lymph nodes, and metastatic sites (**Table 8**). The chance of cure worsens with the higher stages and the absolute number of involved lymph nodes. The larger the tumor, the worse the prognosis. Tumors with a high content of estrogen and progesterone receptors relapse slightly less and are more receptive to hormonal manipulation, and therefore patients with this tend to live longer. Younger women also do worse than older women, and obesity is a risk for worse prognosis.

Breast cancer usually is found as a painless mass, often first felt by the woman. At the time of discovery, the average size of the lesion is 2.5 cm, and 50% of invasive lesions have already spread to the axillary nodes on the same side (stage II or greater). In contrast, the average size of the breast cancer lesion found on mammography is 0.5 cm and is much less likely to have spread. Mammography, however, has a 10% false negative rate; any mass should be biopsied if there is any doubt to its benign nature. Men with breast cancer may also carry BRCA mutations and should be offered genetic counseling and screening. The carrier status information is important to both the patient and the family, as carriers of BRCA2, the more common mutation in male breast cancer, have a 15–20% lifetime risk of developing breast cancer, and there is an association with familial pancreatic cancer and prostate cancer.

At the time of initial diagnosis, even many early breast cancers have already spread within the breast or have metastasized (metastases too small to be felt). This is why in many cases the patient, after removal of the tumor, is given radiation to the breast (if lumpectomy was chosen rather than mastectomy) and adjuvant chemotherapy to eradicate micrometastases. Tamoxifen (an anti-estrogen to the breast) had been useful particularly in the elderly woman with estrogen receptor-positive tissues. Tamoxifen use is being challenged by a class of drugs known as aromatase inhibitors, which suppress estrogen levels in postmenopausal women by blocking the conversion from androgens, which is the only estrogen source when ovarian function ceases. In a large randomized clinical trial there was prolonged disease-free survival and reduction in the number of contralateral breast cancers in the anastrozole (an aromatase inhibitor) group. There is a decreased incidence of vascular events and endometrial cancer using the aromatase inhibitors, but increased osteoporosis. Aromatase inhibitors are the first recommendation in treatment for metastatic breast cancer, but the current recommendation is to begin with tamoxifen and consider switching after

Table 8 Clinical stages of breast cancer[a]

Stage	*Characteristics*
Stage I	The tumor is 2 cm or smaller and has not spread outside the breast
Stage II	• No tumor is found in the breast, but cancer is found in the axillary lymph nodes (the lymph nodes under the arm), or • The tumor is 2 cm or smaller and has spread to the axillary lymph nodes, or • The tumor is larger than 2 cm but not larger than 5 cm and has not spread to the axillary lymph nodes
Stage IIIA	• No tumor is found in the breast, but cancer is found in axillary lymph nodes that are attached to each other or to other structures, or • The tumor is 5 cm or smaller and has spread to axillary lymph nodes that are attached to each other or to other structures, or • The tumor is larger than 5 cm and has spread to axillary lymph nodes that may be attached to each other or to other structures
Stage IIIB	The cancer may be any size and • has spread to tissues near the breast (the skin or chest wall, including the ribs and muscles in the chest), and • may have spread to lymph nodes within the breast or under the arm
Stage IIIC	• The cancer has spread to lymph nodes beneath the collarbone and near the neck, and • The cancer may have spread to lymph nodes within the breast or under the arm and to tissues near the breast In operable stage IIIC breast cancer, the cancer • is found in 10 or more of the lymph nodes under the arm, or • is found in the lymph nodes beneath the collarbone and near the neck on the same side of the body as the breast with cancer, or • is found in lymph nodes within the breast itself and in lymph nodes under the arm In inoperable stage IIIC breast cancer, the cancer has spread to the lymph nodes above the collarbone and near the neck on the same side of the body as the breast with cancer
Stage IV	The cancer has spread to other organs of the body, most often the bones, lungs, liver, or brain

[a] Adapted from http://www.cancer.gov. T (tumor), N (nodes), and M (metastases) staging systems for all cancers are available through the American Joint Committee on Cancer (AJCC).

2 years to an aromatase inhibitor based on a study showing a benefit of letrozole (an aromatase inhibitor) after tamoxifen. Women need to be carefully monitored with yearly bone density and should take calcium and vitamin D and other medications to prevent bone loss if needed.

Cancer of the Prostate

Prostate cancer is the most common cancer in men and is second only to lung cancer as a cause of cancer death. It is responsible for over 3% of all deaths in men over age 55. The age-specific mortality rate is double in African American men as compared to Whites. In 2005, it was estimated that 232 090 men will be diagnosed with prostate cancer, and more than 30 350 will die from prostate cancer. More than one-half of men diagnosed with prostate cancer die within 10 years. Cancer of the prostate is the most common malignancy in human beings if one looks at autopsy data. Over 40% of men over the age of 75 have cancer in their prostate glands, but over a lifetime only 23% of these men will develop clinical disease, and only 7% of them will die of the disease. Thus, there is a great difference between having histologic evidence of the disease and actual clinical problems from it.

The incidence and mortality from prostate cancer in the United States has climbed steadily since 1970, particularly in Blacks. In American Blacks, cancer of the prostate is more often diagnosed in later stages and is more likely to be poorly differentiated, and survival time is shorter than in Whites. In contrast, Black Africans have a low incidence of the disease. The incidence of cancer of the prostate is low in Asia, but rises in Asian immigrants to the United States. American Inuit have a low risk for prostate cancer as compared to Americans in general or to other native American groups.

Levels of testosterone and diet have been identified as a possible explanation for these epidemiological differences. American Blacks have higher testosterone levels than Whites or African Blacks. The dietary factors that are suspected include quantity and type of fat, low selenium, low carotene, and high protein. It appears that unsaturated fat is a greater risk than saturated fats. Omega-2 fatty acids found in seafood, as eaten by the Inuit, may be protective. Other possible risks include industrial pollutants, high cadmium, and genetic factors.

Cancer of the prostate may be described as either clinically important (threatening the life or well-being of the patient) or clinically unimportant (latent and not a threat to the person harboring it). However, time is critical in determining whether a

cancer that is clinically unimportant becomes important. Many men will have a latent cancer, which, if given enough time, will go through the multistep process necessary to develop into a clinically important malignancy. The latent cancers are usually small, well-differentiated, and non-invasive, and there is a normal serum prostate-specific antigen (PSA) that does not rise. The clinically important cancers are larger, poorly differentiated, and invasive, and the serum PSA is high and keeps rising.

For many elderly men, if there is a life expectancy of fewer than 10 years, or if the patient has a disease that is likely to be fatal in the near future, one does not have to rush to treat the patient. Watchful waiting is indicated in men over the age of 70 if they have a normal to minimally abnormal digital rectal exam, a low Gleason score (<7), fewer than three involved cores with 50% or less tumor involvement on individual cores, and slowly increasing serum PSA (<1 ng/ml/year). Patients with more aggressive tumors should undergo definitive therapy.

The most common type of cancer in the prostate is adenocarcinoma, accounting for almost 98% of all cancers. The tumors may be well, moderately, or poorly differentiated. They are usually clinically staged, as shown in **Table 9**. Most patients with early-stage disease are asymptomatic at the time of diagnosis. As the tumor grows, it may lead to obstructive symptoms of the bladder or urethra, such as frequency of urination, nocturia, hesitancy, and narrow urinary stream. As the disease spreads locally, it may lead to constipation and lymphedema of the legs. It usually metastasizes to bone, and the patient may present with low back pain, which can be mistaken for arthritis.

Cancer of the prostate can be diagnosed by ultrasonography and core needle biopsy if there is an elevated PSA or if a nodule is felt on rectal examination of the prostate gland. Many men taking the PSA test are found to have mild elevations (4–10 mg/ml), which are non-specific, as a benignly enlarged prostate will give these readings. In addition, the test is not very sensitive, as about 10% of men with normal PSA levels have carcinoma of the prostate. Only about 25% of men with PSA levels of 4–10 mg/ml will have cancer, but about 65% of men with a PSA of greater than 10 mg/ml will have cancer of the prostate. Thus, the sensitivity and specificity of the test is not as good as one would like using 4 mg/ml as a cutoff point for abnormal levels. Using a cutoff of 10 mg/ml, the detection of patients with cancer is 25% of patients were stage A, 35% were stage B, 50% were stage C, and 65% were stage D. Unfortunately, in African Americans and patients with a family history the cutoff may actually need to be lower. The velocity of PSA rise and PSA density may prove helpful.

Table 9 Clinical stages of cancer of the prostate[a]

Stage	*Characteristics*
Stage 0	Cancer is limited to the mucosa (carcinoma *in situ*) and is found only during surgery for other reasons, such as benign prostatic hypertrophy (BPH)
Stage I	Cancer is found in the prostate only. It cannot be felt during a digital rectal exam and is not visible by imaging. It is usually found accidentally during surgery for other reasons, such as BPH. Stage I prostate cancer may also be called stage A1 prostate cancer
Stage II	The cancer is more advanced than in stage I, but has not spread outside the prostate. Stage II prostate cancer may also be called stage A2, stage B1, or stage B2 prostate cancer
Stage III	Cancer has spread beyond the outer layer of the prostate to nearby tissues. Cancer may be found in the seminal vesicles. Stage III prostate cancer may also be called stage C prostate cancer
Stage IV	Cancer has metastasized (spread) to lymph nodes near or far from the prostate or to other parts of the body, such as the bladder, rectum, bones, liver, or lungs. Metastatic prostate cancer often spreads to the bones. Stage IV prostate cancer may also be called stage D1 or stage D2 prostate cancer

[a] Adapted from http://www.cancer.gov. T (tumor), N (nodes), and M (metastases) staging systems for all cancers are available through the American Joint Committee on Cancer (AJCC).

Cancer of the Bladder

More than 50 000 new cases of cancer of the bladder are diagnosed annually in the United States; about 10 000 people die of it. The older one gets, the more likely he or she is to develop bladder cancer, and the survival rate is lower with advancing age.

Cancer of the bladder is more common in men, and is related to occupational exposure to aryl amines such as those found in workers in the organic chemical, dye, rubber, and paint industries. The strongest association is found in cigarette smokers. Other associations are in people with chronic inflammation of the bladder. There have been fears that artificial sweeteners (cyclamate and saccharin) may induce bladder cancer, but this has not been shown in humans.

In the United States, approximately 95% of all bladder cancers are transitional cell carcinomas. About 3% are squamous cell, and the rest are adenocarcinomas. Most bladder tumors are papillary

Table 10 Clinical stages of cancer of the bladder[a]

Stage	*Characteristics*
Stage 0	Cancer is found only on tissue lining the inside of the bladder • Stage 0 is also called papillary carcinoma, which may look like tiny mushrooms growing from the lining of the bladder • Stage 0 is also called carcinoma *in situ*, which is a flat tumor on the tissue lining the inside of the bladder
Stage I	Cancer has spread to the layer below the inner lining of the bladder
Stage II	Cancer has spread to either the muscle wall or the bladder
Stage III	Cancer has spread from the bladder to the fatty layer of tissue surrounding it, and may have spread to the reproductive organs (prostate, uterus, vagina)
Stage IV	Cancer has spread from the bladder to the wall of the abdomen or pelvis, to one or more lymph nodes, or to other parts of the body

[a] Adapted from http://www.cancer.gov. T (tumor), N (nodes), and M (metastases) staging systems for all cancers are available through the American Joint Committee on Cancer (AJCC).

Table 11 Clinical stages of cancer of the kidney[a]

Stage	*Characteristics*
Stage I	Tumor is confined to the kidney and no larger than 7 cm
Stage II	Tumor is confined to the kidney and is larger than 7 cm
Stage III	• Cancer is in the kidney and in one nearby lymph node, or • the cancer has extended to the adrenal gland or in the layer of fatty tissue (perinephric fat) around the kidney, and may be found in one nearby lymph node, or • the cancer has spread in the main blood vessels of the kidney (renal vein) and may be found in one nearby lymph node
Stage IV	• Cancer has spread beyond the layer of fatty tissue around the kidney and may be found in one nearby lymph node, or • the cancer has spread to two or more nearby lymph nodes, or • the cancer has spread to other organs, such as the bowel, pancreas, or lungs, and may be found in nearby lymph nodes

[a] Adapted from http://www.cancer.gov. T (tumor), N (nodes), and M (metastases) staging systems for all cancers are available through the American Joint Committee on Cancer (AJCC).

transitional cell carcinomas. They are classified into three grades. Grade 1 is well differentiated with limited atypia and mitoses. Grade 3 lesions have a marked increase in cell layers and cell size with marked pleomorphism and mitoses. Grade 2 is intermediate. It is believed that cancer of the bladder arises by damage to the bladder endothelium by carcinogens, infections, stones, or other foreign bodies (such as indwelling catheters), which lead to hyperplastic growth and immature cells. This will progress (multiple hits) through metaplasia to carcinoma *in situ*, and finally invasive carcinoma.

Clinical staging of cancer of the bladder is shown in **Table 10**. The lower the stage and grade, the better the prognosis. Cancer of the bladder tends to occur as multiple lesions and tends to recur.

Most patients with cancer of the bladder present with painless hematuria. If any red cells are persistently found on urinalysis, cystoscopy is indicated. Less frequently, the patient will complain of dysuria and frequency. Advanced cancer is rare as a presenting symptom, as most people will go to a doctor when blood is noted in the urine.

Cancer of the Kidney

More than 25 000 cases of cancer of the kidney are diagnosed annually, with close to 11 000 deaths; this represents about 3% of cancer deaths. Cancer of the kidney is more common in men than women, and is most common from age 50 to 70.

The risk factors for cancer of the kidney include cigarette smoking, obesity, and analgesic abuse. Other environmental factors include asbestos, cadmium exposure, and working in the leather industry. Patients with end-stage kidney disease who develop cysts are also at increased risk.

The most common histologic type of kidney cancer is adenocarcinoma. Tumor grading is not used frequently in this type of malignancy. Clinical staging is shown in **Table 11**. In more than half of patients, metastatic disease is present at time of diagnosis.

Cancer of the kidney clearly presents as gross hematuria, pain, and flank mass, but this is found in only about 20% of cases. Many times the disease can be noted by painless microscopic hematuria or is found when the patient presents with systemic symptoms such as anemia, fever, weight loss, and fatigue. Rarely, the patient may have polycythemia. Early disease can be detected only by evaluating any microscopic hematuria.

Cancer of the Ovary

Ovarian cancer is the sixth most common cancer of women in the United States but is the fourth leading

cause of cancer death. More women die from ovarian cancer than from cervical and endometrial cancer combined. Approximately 22 000 new patients are diagnosed every year, and 16 000 women die. Cancer of the ovary increases with age, peaking at age 80. Approximately 1% of all female deaths are from cancer of the ovary.

Ovarian cancer is usually found in industrialized nations, with the notable exception of Japan. Japanese Americans have a higher incidence of ovarian cancer than Japanese in Japan, but the incidence is still lower than in the White population. In the United States, ovarian cancer is most common in White women. Risk factors include a low number of pregnancies (each pregnancy lowers the risk by about 10%), use of anticonvulsant drugs, history of breast cancer, and exposure to asbestos and talc. Birth control pills lower the risk of developing ovarian cancer.

Most cancer of the ovary is of the epithelial type, and in women over 65 this type accounts for 95% of the cases. Cancer of the ovary spreads early by surface shedding, lymphatic spread, and, less commonly, blood-borne metastases. Over 50% of women presenting with this cancer have disease spread outside of the pelvis (stage III or IV). **Table 12** shows the staging used for ovarian cancer. Older women will present with a stage III or IV disease about 65% of the time.

Ovarian cancer is usually asymptomatic until it spreads. By the time the woman notices pain, abdominal swelling, vaginal bleeding, or GI distress, the disease is widespread. The only way to identify disease early is by finding an adnexal mass via a pelvic examination. Any adnexal enlargement in a postmenopausal woman should be considered a malignancy until proven otherwise. Ultrasound is useful in detecting ovarian masses but is considered too expensive to use for routine screening.

Table 12 Clinical stages of cancer of the ovary[a]

Stage	*Characteristics*
Stage I	Cancer is found in one or both of the ovaries and has not spread Stage IA: Cancer is found in a single ovary Stage IB: Cancer is found in both ovaries Stage IC: Cancer is found in one or both ovaries and one of the following is true: ● cancer is found on the outside surface of one or both ovaries, or ● the capsule (outer covering) of the tumor has ruptured (broken open), or ● cancer cells are found in the fluid of the peritoneal cavity (the body cavity that contains most of the organs in the abdomen) or in washings of the peritoneum (tissue lining the peritoneal cavity)
Stage II	Cancer is found in one or both ovaries and has spread into other areas of the pelvis Stage IIA: Cancer has spread to the uterus and/or the fallopian tubes (the long slender tubes through which eggs pass from the ovaries to the uterus) Stage IIB: Cancer has spread to other tissue within the pelvis Stage IIC: Cancer has spread to the uterus and/or fallopian tubes and/or other tissue within the pelvis and cancer cells are found in the fluid of the peritoneal cavity (the body cavity that contains most of the organs in the abdomen) or in washings of the peritoneum (tissue lining the peritoneal cavity)
Stage III	Cancer is found in one or both ovaries and has spread to other parts of the abdomen Stage IIIA: The tumor is found only in the pelvis, but cancer cells have spread to the surface of the peritoneum (tissue that lines the abdominal wall and covers most of the organs in the abdomen) Stage IIIB: Cancer has spread to the peritoneum but is 2 cm or smaller in diameter Stage IIIC: Cancer has spread to the peritoneum and is larger than 2 cm in diameter and/or has spread to lymph nodes in the abdomen or onto the surface of the liver
Stage IV	Cancer is found in one or both ovaries and has metastasized (spread) beyond the abdomen to other parts of the body. Cancer is found in the tissues of the liver

[a] Adapted from http://www.cancer.gov. T (tumor), N (nodes), and M (metastases) staging systems for all cancers are available through the American Joint Committee on Cancer (AJCC).

Cancer of the Uterus

Cancer of the uterine cervix can and does occur in elderly women. However, the peak age occurrence is between age 48 and 55. Hopefully, vigorous annual screening of young women (Pap smears) will result in fewer cases in older women. It is recommended that Pap smears be done in elderly women who have not been adequately screened up to the age of 65. Up to 60% of women over the age of 65 have not had a Pap smear taken.

Cancer of the endometrium is the most common of all gynecologic cancers. The peak age range for developing this cancer is 60–64. It is a relatively easy cancer to detect; it spreads late and Pap smears will detect about 50% of them. The key to detecting gynecologic cancers in older women is them having an annual pelvic exam.

Other Cancers

Cancer can arise in any organ of the body, including the skin and hematopoietic tissues. In all of these systems, the same principles discussed earlier apply: to develop cancer there must be multiple hits resulting in greater degrees of undifferentiation and spread. As a general rule, therefore, given the time necessary to develop a malignancy, the elderly are more likely to have almost any malignancy.

The original histologic grading and clinical staging for malignancy were done in Hodgkin's disease, and then the other lymphomas. These principles are now applied to all cancers and have proven useful in predicting cure rates and in devising therapeutic regimens.

Unfortunately, cure rates for many malignancies are still very low. Cancer of the pancreas, stomach, esophagus, brain, liver, multiple myeloma, and acute leukemia all carry very poor prognoses. As a general rule, in the elderly, cancer presents in a more advanced form and is more likely to have metastasized, and the patient is less likely to be able to tolerate much therapy.

Screening for Cancer

The goal of screening for cancer is to detect disease at an early point and to be able to institute curative therapy at that time. Any screening procedure must meet certain criteria to be used: it must be safe, inexpensive, and easy to do and have high sensitivity and specificity. The illness being screened should be common and a cure must be available.

There are four benefits sought in any cancer screening program. The primary benefit is finding a disease that would be fatal if left untreated. The second benefit is that disease found early requires less harmful therapy. Third, it is cheaper to society if cancer is found early, and finally, those who test negative for the disease are reassured. However, any screening program also has many disadvantages. In many cancers that are detected the prognosis is not changed, so that the morbidity to the patient is actually longer. Second, screening may result in findings that, if left alone, would not have harmed the patient. The third disadvantage is that false-positive tests lead the physician to order many other tests, which causes considerable anxiety to the patient. Fourth, many of the diagnostic tests can in themselves be harmful. The fifth disadvantage is cost to society, and, finally, false-negative tests will falsely reassure the patient.

Due to these considerations, extensive cancer screening is usually reserved for cervix, breast, and colon. While there are advocates for screening for cancer of the prostate and lung, this is not universally accepted. The current (2005) recommendations for screening are shown in **Table 13**. These are in flux, as most screening programs have not shown a reduction in the mortality or morbidity of the cancer being studied. Most people, however, follow these suggestions.

Principles of Cancer Therapy

The mainstays of cancer therapy are surgery, radiation, and chemotherapy. Newer methods of therapy are bone marrow transplantation, use of cytokines, immunotherapy, hormones and anti-hormones, and gene therapy. The elderly are candidates for cancer therapy; indeed, all too often they are denied therapy because either the doctor or the patient and his or her family are misguided as to the benefits of treatment. In many instances the elderly do better with therapy than the young.

Surgery

Surgery is the oldest treatment for cancer and until recently was the only therapy that could cure cancer patients. Surgical treatment has changed drastically since the 1980s. Advances in surgical techniques and a better understanding of the patterns of spread of individual cancers have led to more successful operations, and the development of alternate and adjunct treatment strategies has led to less extensive surgery.

Age is not an independent risk factor for surgery. The determinants of surgical risk include the status of the heart, lungs, kidneys, brain, liver, hematopoietic, and endocrine systems as well as nutritional status and presence of diseases such as diabetes. An elderly patient who is healthy can withstand surgery as well as a young person by using newer methods of anesthesia and postoperative monitoring.

Surgery can be used for six different reasons:

1. Removal of primary cancer
2. Reduction of bulk of residual disease
3. Resection of metastatic disease with curative intent
4. Treatment of an emergency situation in cancer, such as bleeding or infection
5. Palliation
6. Reconstruction and rehabilitation

Radiation Therapy

Radiation therapy may be used as either primary therapy or as an adjunct to surgery or chemotherapy.

Table 13 American Cancer Society cancer detection guidelines

Cancer site	*ACS test or procedure and frequency recommendations*
Breast	Clinical breast exam: self-exam monthly beginning at age 20; physician exam every 3 years at ages 20–39, yearly after age 40 Mammogram: annually after age 40 (?role after age 80)
Cervix	Annual Pap smear within 3 years of vaginal intercourse or by age 21; after age 30 and three negative consecutive smears, perhaps every 3 years with convention of liquid-based Pap plus the HPV DNA. Women over 70 with three normal consecutive Pap tests and no abnormal within 10 years may choose to stop having cervical cancer screening at discretion of physician. Women after total hysterectomy may choose to stop having cervical cancer testing unless the treatment was for cervical cancer or precancer
Colon-rectal	Yearly exam after age 40; yearly fecal occult blood after age 50; sigmoidoscopy every 5 years after age 50; or barium enema every 5 years or colonoscopy every 10 years. All positive tests should be followed with colonoscopy. Higher-risk patients, those with personal history of colorectal cancer or adenomatous polyps, strong family history (first-degree relative younger than 60 or two first-degree relatives at any age), personal history of inflammatory bowel disease, or family history of a hereditary colon cancer syndrome (hereditary non-polyposis colon cancer [HNPCC] or familial adenomatous polyposis [FAP]), should begin screening earlier and more often usually with colonoscopy
Endometrial	Women should be informed about the risks and symptoms of endometrial cancer and should report any unexpected bleeding or spotting to their doctors. Women with HNPCC should be offered frequent screening, with endometrial biopsy beginning at age 35
Lung	Currently no recommendations. Chest X-rays are generally not useful as a screening tool. CT investigation of heavy smokers is ongoing
Prostate	Digital rectal examination of the prostate and PSA blood test yearly beginning at age 50 for men with a life expectancy of greater than 10 years. African American men or men with a family history of prostate cancer in a first-degree relative should begin at age 45 (this recommendation is controversial)
Skin cancer	Counseling on avoiding sun exposure, and skin exam every 3 years between 20 and 40 and yearly after age 40
Testicular	Examination of testicles as part of a cancer-related check-up
Cancer-related check-up	At the periodic health examination, the cancer-related check-up should include examination for cancers of the thyroid, testicles, ovaries, lymph nodes, oral cavity, and skin, as well as health counseling about diet and nutrition, sun exposure, risk factors, sexual practices, and environmental and occupational exposures

Primary radiation therapy is often used in the elderly with multiple diseases who are poor surgical risks, as there is no appreciable acute mortality from irradiation. Associated medical conditions do not contraindicate curative treatments. Other advantages of radiation in the frail elderly are preservation of function in the organ from which the cancer originates, and delivery of curative treatment even when the anatomic boundaries of the tumor are not amenable to surgery.

The disadvantages of radiation therapy include the disturbing side effects, the length of time of treatment (up to 2 months), and the development of secondary malignancies. Secondary malignancies are of less concern in the very old, however.

Newer methods and equipment have made radiation therapy much more tolerable. Certainly secondary or adjuvant radiotherapy with limited surgery and chemotherapy is very attractive to older people. Limited surgery followed by local radiation treatment decreases the morbidity of either treatment alone. Likewise, radiation as an adjunct to chemotherapy allows the physician to decrease the dose of either treatment alone and thus avoid some of the side effects.

Chemotherapy

It has been thought that changes in pharmacokinetics of drugs with age may limit the ability to deliver curative doses of chemotherapy to the elderly. However, there are relatively few studies that have shown this. It is widely accepted that CCNU and methotrexate doses should be reduced in the elderly, and bleomycin toxicity is greater with advancing age. Usually, the limiting factor in delivering chemotherapy is bone marrow reserve, which is decreased in the elderly. However, the wide availability of blood products and growth factors to stimulate bone marrow (such as erythropoietin and colony-stimulating factors) has greatly improved the situation. Bone marrow transplantation has not been well studied in

older people. Bone marrow may be harvested from the patient and retransfused into them after chemotherapy is given (autologous transplantation). Allogenic transplantation from a different donor has not been used in the elderly and is limited mainly to young people.

Chemotherapy is often dreaded by older people because of its systemic symptoms. There is no evidence that the elderly tolerate this form of treatment any worse that the young, nor are there data showing it does not work as well. Many more studies are needed to assess the true value of chemotherapy in the elderly.

Hormonal Therapy

Certain tumors are responsive to hormonal manipulation, notably cancer of the breast and cancer of the prostate. The anti-estrogen tamoxifen has been particularly useful in postmenopausal women with cancer of the breast to palliate metastatic disease and perhaps to prevent development of further disease. Other hormonal therapy, such as oophorectomy, adrenalectomy, and megesterol therapy, has been useful. In cancer of the prostate, orchiectomy, estrogen therapy, the use of luteinizing hormone-releasing hormone (LHRH) agonists to lower testosterone and α-5 reductase inhibitors to block the reduction of testosterone to dihydrotestosterone have been useful in palliation.

Biological Therapy

The use of red blood cell, platelet, and at times granulocyte transfusions and fresh frozen plasma infusions has greatly helped patients overcome the severe effects of anemia, bleeding from thrombocytopenia, and infections from granulocytopenia. Clotting factors, both pooled and recombinant, are available for people who need them. The introduction of recombinant factor VIIa has worked in a variety of hemorrhagic disorders. There are numerous growth factors, such as erythropoietin to stimulate red cell production, granulocyte macrophage colony-stimulating factor (GM-CSF) to stimulate production of both granulocytes and macrophages, granulocyte colony-stimulating factor (G-CSF) to stimulate granulocyte production, and recombinant human interleukin-11 that stimulates production of hematopoietic stem cells and megakaryocyte progenitor cells and induces megakaryocyte maturation, which increases platelet production. Interleukin-3, which increases neutrophils and easinophiles and sometimes basophiles and platelets, and megakaryocyte growth and differentiation factor, which is a thrombopoietin, can increase platelets but are not yet available in the clinic. Studies using combinations of these factors to enable the cancer patient to receive more intensive curative therapies by alleviating cytopenias are in progress.

Immunotherapy in cancer therapy is also being widely studied. Immune cells secrete two types of soluble proteins: antibodies and cytokines. Both of these have the ability to destroy tumor cells. Specific tumor antibodies may be directed against the person's own cancer and are being studied as a means of therapy in designer vaccine trials. The cytokines, which are actually hormones produced in the immune system, are potentially very useful. Studies have been done with interferons and interleukin-2, which are promising in some cancers. Non-specific immunotherapy to increase the immune system has been widely tried with BCG, a modified form of the tubercle bacillus. This has not been very successful, but it is hoped that more-specific immunotherapy with monoclonal antibodies and specific cytokines will be of greater value.

Targeted Therapy

The most exciting advances in cancer therapy come from 'targeted therapy,' which is a type of treatment that uses drugs or other substances to identify and block the growth and spread of specific cancer cells without harming normal cells. Examples of these therapies are monoclonal antibodies, small molecules that block enzymes, antisense molecules, apoptosis-inducing drugs, cancer vaccine, and gene therapy.

Monoclonal Antibodies Cetuximab (Erbitux) is a monoclonal antibody that binds specifically to the human EGFR and that has proven efficacy in metastatic colon cancer as well as other malignancies that express EGFR by blocking this receptor so that the cells do not grow. Bevacizumab (Avastin) is a monoclonal antibody directed against VEGF with efficacy in treating colorectal cancer and other tumors expressing VEGF by interfering with tumor blood vessel formation. Rituximab is a monoclonal antibody against the cell surface receptor CD20 and is used to treat CD20+ lymphomas by coating the cells, resulting in both increased clearance and apoptosis. Ibritumomab tiuxetan (Zevalin) is a monoclonal antibody similar to rituximab linked to a radioactive particle that targets CD20+ tumor cells and kills them. Trastuzumab is a monoclonal antibody used to treat Her2+ breast cancers by targeting that gene product, resulting in apoptosis.

Small Molecules Imatinib mesylate is a small molecule protein tyrosine kinase inhibitor that inhibits the Bcr-Abl tyrosine kinase, the constitutive abnormal

tyrosine kinase created by the Philadelphia chromosome abnormality in chronic myeloid leukemia (CML). This drug is used to treat CML and gastrointestinal stromal tumors (GIST) with the abl tyrosine kinase mutation. BAY 43-9006 (Sorafenib) is another specifically engineered molecule that inhibits RAF kinase in the cancer cells which is part of the RAS oncogene pathway. RAS is a gene that drives cell division and is overexpressed in many cancers, including renal cell carcinoma. This drug has efficacy in treating renal cell carcinoma, may additionally inhibit VEGF and platelet-derived growth factor (PDGF), which are receptor kinases, and may have efficacy in treating a wide variety of malignancies, as RAS mutations are the most common mutations in human malignancy. Erlotinib (Tarceva) and Gefitinib (Iressa) are two other small molecule receptor tyrosine kinases against EGFR shown to be effective in lung cancer.

Drugs That Induce Apoptosis Oblimersen (Genasense) is a molecule directed against the normal RNA responsible for making bcl-2, which promotes cell survival. This drug is currently in clinical trials (2005). Blockade of bcl-2 will lead to apoptosis and increased sensitivity to chemotherapy drugs. Bortebomib (Velcade) causes cells to die by blocking enzymes called proteosomes, which regulate cell function and growth. This drug induces apoptosis and is approved for use in multiple myeloma and cancer of plasma cells, which are one type of the white cells in the body that treats infection.

Cancer Vaccines Clinical trials with vaccines against cervical carcinoma human papillomavirus (HPV) and designer vaccines against lymphoma or melanoma cells, prostate, and colon cancer are some of the ongoing areas of interest.

Gene Therapy

Several goals can be accomplished by gene therapy. Replacement of missing or altered genes with normal genes may prevent cancer from developing and allow the malignant cells to die a normal programmed death; genes can be introduced to improve a patient's immune response to the cancer; genes can be introduced into normal cells to allow the administration of high doses of chemotherapy to kill the malignant cells and spare the normal ones; suicide genes can be introduced into cancer cells and later be turned on by a drug metabolized by the cancer cell; or genes can be introduced to inhibit the formation of new blood vessels. Scientists continue to work on ways to deliver the vector (carrier of the gene into the cell), which is usually done with an altered virus. The danger is that the gene may be inserted into the wrong cell or the wrong location in the DNA, causing a mutation and potentially cancer or another harmful condition. Preclinical research is ongoing.

Supportive Care and Quality of Life

In caring for cancer patients, it is clear that there are numerous problems that must be addressed. Often the patient has considerable pain, is nauseated and vomiting, is not eating, and is depressed. Any cancer program must deal with these issues in order to achieve any quality of life.

Pain

Numerous studies have shown that 30–50% of patients undergoing cancer therapy and 60–90% of patients with advanced disease experience pain. Pain is considered the fifth vital sign. Providers routinely assess patients for pain every time that pulse, blood pressure, core temperature, and respiration are checked. The use of pain scales, either numeric or visual (analog or faces), allows assessment of response to pain control measures in the individual. Patient pain logs correlating medications, activity, type of pain, intensity, duration, and relieving and exacerbating factors help the clinician titrate the medications.

The most effective pain management is a multidisciplinary approach with anesthesiology, neurology, physical therapy, psychology, and oncology. The goal is to allow the patient sufficient relief of pain in order to maintain an acceptable quality of life and continue with the activities of daily living and cancer therapy. For terminally ill patients, the goal is to allow them to function at a level they choose and to die free of pain.

Drug therapy should be effective in virtually all patients. With mild to moderate pain, non-opiate drugs are used, such as acetaminophen and nonsteroidal anti-inflammatory medications. The opioid medications used to treat moderate to severe pain include morphine, fentanyl, oxycodone, and hydromorphone. Meperidine should not be used, as it causes CNS irritability. Fentanyl transdermal patches or oral transmucosal fentanyl citrate, a strong opioid analgesic, have been very useful albeit expensive additions to treat chronic pain. Patient-controlled analgesia (PCA) using an intravenous drip regulated by the patient, once relegated to the preterminal patients, is now a common occurrence in hospitalized patients to achieve quick pain control and an easy switch to an equianalgesic oral and/or transdermal regimen. When using narcotics, it is essential to use the drugs 'around the clock' – in other words, they should be used to

prevent pain, not given only when the pain occurs. This can usually be accomplished with long-acting agents. Combinations of drugs to potentiate the opiates are very useful. All possible approaches should be tried, such as acupuncture, injection of painful sites, physical therapy, nitrous oxide, hypnotism, biofeedback, guided imagery, meditation, and prayer. If need be, surgical procedures such as cordotomy, local blocks of nerves, or implantation of a programmable intrathecal drug delivery pump should be done. In addition to analgesics, other drugs may be used to treat associated depression, sedation, nausea, and constipation. The goal is to eliminate pain.

Nausea and Vomiting

Great strides have been made in the development of antiemetics. The substituted benzaimides that block serotonin receptors (specifically the type 3 or 5-HT3 receptors) are the standard of care. Substance P/neurokinin 1 (NK_1) receptor antagonists are being developed; aprepitant was the first one introduced in the United States. NK_1 receptor blockade augments the central antiemetic effect of 5-HT3 receptor antagonists and dexamethasone, resulting in reduced emesis from highly emetogenic agents, e.g., cisplatin. The phenothiazines, metoclopramide (central and peripheral dopamine receptor agonists), benzodiazepines (lorazepam), butyrophenones (haloperidol), phenothiazines (prochloperazene), corticosteroids, and cannabinoids are also useful.

Nutritional Support

Cancer cachexia is a well-described syndrome of progressive weight loss and anorexia mediated by a variety of cytokines elaborated by the cancer or the host, e.g., TNF. Control of mucositis, nausea and vomiting, pain, constipation, and shortness of breath help to allow the patient to eat and drink, but weight loss may continue. It is essential to offer the patient high-calorie and high-nutrient food supplements, to use intravenous therapy when necessary, even at home, and to consider the use of gastrostomy tube feedings if wanted. Tube feedings may be stopped if and when the patient can eat or no longer chooses this therapy.

Psychological and Social Supports

The care of patients with cancer requires a multidisciplinary team. Most cancer centers provide supportive care, including psychological, social work, nutritional, pain management, physical rehabilitation, and spiritual continuing care programs. These programs have been developed to help cancer survivors as well as dying patients both in the hospital and at home. When the focus of treatment shifts from curative therapy to symptom control and palliative comfort, home-care services, home- and hospital-based teams, and home- and hospital-based hospice care are readily available for the patient and the family. Both the patient and the family need help, supportive psychotherapy, and preparation for death. The team is available 24 hours a day. Nurses, social workers, and physicians work together with the patient and family to achieve comfort and a dignified death. Support groups for the surviving family members and friends are also available.

See also: Cancer: Breast; Cell Death; Diet and Nutrition; Hospice; Prostate.

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http://www.thegoc.org – Geriatric Oncology Consortium.
http://www.cancerworld.com – International Society of Geriatric Oncology.
http://www.cancer.gov – National Cancer Institute.
http://www.nccn.org – NCCN Clinical Practice Guidelines in Oncology.

Cancer: Breast

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Glossary

Adjuvant Treatment – Treatment given to help the primary treatment succeed.

Lymph Node Mapping – Injection of a supra-vital dye or a radioactive tracer around a tumor, which allows the detection of the first lymph nodes where the tumor lymphatics drain. These lymph nodes are biopsied and if they are free of tumors, no further surgery is necessary.

Neoadjuvant Treatment – Treatment given prior to primary treatment, with different goals, including to reduce the size of the primary tumor and to allow partial mastectomy and organ preservation, as well as to assess the responsiveness of a tumor to systemic treatment.

Introduction

Breast cancer is the most common cancer in US women, and approximately 50% of breast cancers occur in the 12% of women aged 65 and over. With the growth of the older population, by the year 2030 almost two-thirds of breast cancers will affect elderly women. Though breast cancer becomes more indolent with the age of the patient, the mortality related to breast cancer has decreased by approximately 10% for women younger than 65 and has increased by the same proportion for those older, indicating that better control of this malignancy is needed, especially for the older women. Another important consideration is that breast cancer affects preferentially women in good general health, that is, women whose life expectancy is not lessened by comorbidities or functional limitations and for whom breast cancer is a cause of death. After examining potential causes of breast cancer, this article explores the prevention and the management of this neoplasm in older women.

Etiology of Breast Cancer

The most important risk factor of breast cancer is age. At least 10–15% of breast cancers are familial, and a number are clearly hereditary. Of these, the best-defined forms are related to a number of mutations in two genes: BrCa-1 (also associated with ovarian cancer), and BrCa2. The vast majority of hereditary breast cancers are seen in women under the age of 50. Prophylactic mastectomy in individuals at risk prevents the development of hereditary breast cancer. This practice may then minimize the incidence of hereditary breast cancer in older women.

Hormone replacement therapy (HRT) appears a major risk factor in older women, as suggested by several retrospective studies and demonstrated in the prospective and randomized Women Health Initiative, in which postmenopausal women were randomized to receive HRT or placebo. HRT consisted of a combination of estrogen and progesterone for women with uterus, and estrogen alone for those posthysterectomy. The combination of estrogen and progesterone may increase the risk by 50% and is associated with increased breast cancer mortality. The risk increases with the duration of the treatment and abates when the treatment is discontinued. With estrogen alone, the risk of breast cancer and its mortality is smaller, and may not be increased at all.

Obesity, especially the male type of obesity, defined as a ratio between the hip and waist circumference of less than 0.71, is also a risk factor, probably because abdominal fat is rich in aromatase, which transforms ovarian and adrenal androgens into estrogens, and because male obesity is associated with lower circulating levels of sexual hormone binding.

Diet may have a minor role. The role of dietary fat is controversial; while a number of cross-sectional and retrospective studies suggested that high dietary fat may enhance the risk of breast cancer, the Nurse Health Study, a cohort study of nurses followed for more than 10 years, failed to confirm this suggestion. A recent randomized controlled study, however, demonstrated that dietary fat restriction may reduce the risk of breast cancer recurrence after surgery. How this data may apply to the risk of breast cancer is not clear. There is good evidence instead that regular alcoholic intake may increase the risk and that this may be somehow counteracted by the addition of folates to the diet.

Biology of Breast Cancer and Its Relationship to Aging

The most important prognostic factor of breast cancer is stage at the time of diagnosis (**Table 1**). Carcinoma *in situ* is represented by three different

Table 1 TNM staging system of breast cancer[a]

Classification	*Description*
Primary tumor (T)	
Tx	Primary tumor not assessable
T0	No evidence of primary tumor
Tis	Carcinoma *in situ*
T1	Tumor largest diameter $\leq$2 cm
T1a	Tumor between 0.1 and 0.5 cm
T1b	Tumor $>$0.5 but $\leq$1 cm
T1c	Tumor $>$1 but $<$2 cm
T2	Tumor largest diameter between 2 and 5 cm
T3	Tumor largest diameter $>$5 cm
T4	Any size tumor with direct invasion of chest wall and/or skin
T4a	Chest wall but not pectoralis muscle
T4b	Edema, or skin ulceration or satellite nodes
T4c	Both T4a and T4b
T4d	Inflammatory carcinoma
Ge	
Lymph node, (LN) clinical classification (N)	
Nx	Regional LN not assessed
N0	No LN metastases
N1	Palpable axillary ipsilateral LN
N2	Matted (fixed) axillary LNs or ipsilateral mammary LNs in absence of axillary LNs
N3	Infraclavicular ipsilateral LNs
	Ipsilateral mammary LNs in presence of axillary LN metastases
	Ipsilateral supraclavicular LN
Lymph node, pathological classification (pN)	
pNx	Regional LN not assessed
pN0	No LN metastases
pN1	Metastases to 1–3 axillary or mammary LNs
pN2	4–9 axillary LNs or clinically evident mammary LNs in absence of axillary LNs metastases
pN3	10+ axillary LNs, or involvement of infraclavicular or supraclavicular LN or in clinically apparent mammary LNs with positive axillary LN
Metastases (M)	
Mx	Distant metastases not assessed
M0	No distant metastases
M1	Distant metastases present
Final staging	
0	Tis N0 M0
I	T1 N0 M0
IIA	T0 N1 M0
	T1 N1 M0
	T2 N0 M0
IIB	T2 N1 M0
	T3 N0 M0
IIIA	T0 N2 M0
	T1 N0 M0
	T3 N1 M0
	T3 N2 M0
IIIB	T4 Any N M0
	Any T N3 M0
IV	Any T Any N M1

[a] Note: The initial staging is based on the clinical evaluation of the patient. After surgery, treatment is based on the pathological staging, that is, on the presence or absence of involvement of axillary LNs.

pathologies: ductal carcinoma *in situ* (DCIS); lobular carcinoma *in situ* (LCIS), and Paget's disease. For early-stage tumors, the invasion of axillary lymph nodes predicts the risk of systemic tumor recurrence. In addition to stage, other important factors including concentration of hormone receptors, tumor grade, and overexpression of Her-2/neu hormone receptors distinguish two types of breast cancer with different biology. One type, which represents two-thirds of all breast cancer and becomes more common with aging, is dependent on sexual hormones for its growth and is characterized

by the presence of receptors for estrogen and progesterone in the tumor cells; the other type is hormone independent and does not express hormone receptors. As a rule, hormone-dependent tumors are more indolent and produce metastases that are not life-threatening, including bone, skin, and nodular lung metastasis, while hormone receptor-negative tumors are more aggressive and more likely to give origin to life-threatening metastases, such as hepatic, cerebral, and lymphangitic lung metastases. The distinction is not ironclad. Virtually all tumors contain hormone-independent tumor cells, and tumors with low concentration of hormone receptors tend to behave more as hormone receptor-negative tumors. The grade indicates the degree of differentiation of the tumor cells, and Her2/neu is one of the four recognized receptors for the epidermal growth factor. High grade (that is, poor differentiation) and Her2/neu overexpression mark a more aggressive tumor. Thanks to the microarray techniques, a number of genetic profiles of breast cancer have also been recognized with different degree of aggressiveness, but this technique has been limited so far to the research laboratory.

Age may have apparently divergent effects on the prognosis of breast cancer. On one side, the stage at diagnosis may be higher for older than for younger women, while the prevalence of well-differentiated, hormone receptor-rich, Her-2/neu-negative tumors also increases with age. In addition, endocrine senescence may reduce the growth rate of hormone-responsive tumors. This divergence may be more apparent than real, as the fact that older women are diagnosed with breast cancer at a more advanced stage may simply reflect reduced utilization of screening mammography in older women, and increased mortality may reflect both underutilization of screening and suboptimal treatment, both of which are remediable.

Prevention of Breast Cancer in the Older Woman

Cancer prevention is commonly subdivided into primary and secondary prevention. Primary prevention includes elimination of environmental carcinogens or of other conditions that may favor the development of cancer, chemoprevention, that is, administration of substances that may offset carcinogenesis, and prophylactic mastectomy in women at risk for familial cancer. Secondary prevention includes early diagnosis of cancer by screening of asymptomatic individuals at risk and prevention of cancer death by timely treatment.

Primary Prevention of Breast Cancer in Older Women

As a consequence of the Woman Health Initiative, which has demonstrated the association of HRT with breast cancer and cardiovascular complications, the use of HRT had decreased in postmenopausal women. Another possible form of primary prevention may include fat restriction in the diet. This approach was found feasible, but its value in cancer prevention has not been demonstrated. On the same vein, it is legitimate to hypothesize that weight loss may lead to prevention of breast cancer. While reduction in alcoholic drinks may also prevent breast cancer, this beneficial effect may be balanced by a negative effect on the risk of coronary artery disease and on quality of life.

The best studied form of primary prevention has been chemoprevention. At least three randomized controlled studies have explored the prevention of breast cancer with the selective estrogen receptor modulator (SERM) tamoxifen. The NSABP-P1 study involved approximately 13 000 women with a risk of developing breast cancer over the next 5 years of at least 1.67% according to the Gail model of calculating breast cancer risk, and demonstrated more than 50% reduction in the risk of breast cancer in the tamoxifen-treated group. Two European studies did not confirm this effect, but both studies were underpowered due to the relatively small number of patients, high dropout rate, and variation in the risk of breast cancer. The value of tamoxifen and other SERMs in the prevention of breast cancer has also been suggested by other studies:

- A number of randomized and controlled studies showed that tamoxifen prevents systemic recurrence of breast cancer in women with hormone receptor-rich tumors. The same studies demonstrated that tamoxifen reduced by 40% the risk of contralateral breast cancer.
- Tamoxifen prevents the progression of DCIS, a precancerous lesion, to invasive cancer.
- Another SERM, raloxifene, has been studied for the prevention of osteoporosis. In that randomized and controlled trial, the use of raloxifene was associated with a 70% reduction in new breast cancers.

The evidence that SERMs do prevent breast cancer is very robust, but the clinical values of these compounds is debatable. In the NSABP-P1 trial, the prevention of breast cancer was not associated with a decreased breast cancer mortality. In other words, serial mammograms might be as effective as tamoxifen in preventing breast cancer-related deaths. In

addition, tamoxifen was associated with increased risk of uterine cancer, deep vein thrombosis, and cerebral vascular diseases and with a decline in quality of life secondary to hot flashes and sexual dysfunctions. Tamoxifen prevented only well-differentiated hormone receptor-rich tumors, which are generally very indolent, and did not affect the incidence of more aggressive tumors. In a decision analysis Gail concluded that chemoprevention of breast cancer with tamoxifen may be beneficial to a 70-year-old woman only if her chances of developing breast cancer over 5 years were higher than 7%. At this moment, a general recommendation to use tamoxifen in all postmenopausal women for the chemoprevention of breast cancer cannot be made. Another group of hormonal agents, the aromatase inhibitors, which prevent the conversion of androgens into estrogens, are being investigated for this purpose.

In retrospective studies, two groups of medications seemed to have a chemopreventative effect on breast cancer: the non-steroidal anti-inflammatory agents (NSAIDs) and the cholesterol-lowering statins.

Secondary Prevention of Breast Cancer

The best established modality of breast cancer death prevention is early detection through screening of asymptomatic subjects. In women aged 50–70, serial mammography has reduced by 20–30% the breast cancer-related deaths in eight randomized and controlled studies. The benefits of screening mammography after age 70 have been suggested by a retrospective analysis of the Surveillance Epidemiology and End Results (SEER) data, which demonstrated a reduction in mortality in women older than 70 who had undergone at least two mammographic examinations between ages 70 and 80. The reduction in mortality was demonstrable even in individuals with moderate comorbidity. These data support the screening for breast cancer of women with a life expectancy of 5 years or longer, as the initial survival benefits of screening were seen 5 years after the institution of this program. In the authors' opinion, the benefits of screening older women for breast cancer should not be debated anymore. What should still be a matter of discussion is the most cost-effective form of screening. In particular, the following questions should be addressed:

- What should be the interval between screening mammograms? Most studies demonstrated that mammography every 2 years may be as effective as yearly examinations.
- Does physical examination of the breast by a physician or a nurse increase the yield of early breast cancer? Could this approach substitute for mammography? Physical examination of the breast could be performed at a clinic visit without the need of an additional trip for mammograms. In at least two studies, physical examination of the breast appeared as effective as mammography in detecting early invasive cancers.
- Could we the screening be limited to women at increased risk of breast cancer? In a decision analysis, Kerlikowske et al. demonstrated that limiting screening mammography to women in the upper quintile of bone density (i.e., those at the highest risk) would reduce the cost and inconvenience of screening without increasing the mortality or morbidity from breast cancer. This interesting proposal needs confirmation in the clinical arena.
- What is the best form of breast cancer screening? A number of new techniques, including digital mammography and breast MRI, appear more sensitive to the diagnosis of early breast cancer than the standard mammogram and may further decrease breast cancer mortality.

Diagnosis of Breast Cancer

In less than 10% of cases, a woman presents with symptoms of metastatic disease, especially bone pain; in a small number of cases, the woman or her healthcare provider may detect a palpable breast nodule or an enlarged lymph node; and in the majority of cases, the diagnosis of breast cancer is done with a mammogram. Even women who detect a palpable lesion do need a mammogram to study the appearance and the size of the lesion and to exclude the presence of multiple cancers. The radiographic appearance of a lesion indicates the degree of probability that it is neoplastic. For lesions at high probability an immediate biopsy is indicated; for those at intermediate probability a breast ultrasound may help distinguish the benign from the malignant ones; and for those at low probability a repeated mammogram at 6-month intervals is recommended to establish whether they have enlarged. All lesions should be checked for hormone receptors and for HER2neu. Both tests are performed by immunohistochemistry and the results are graded according to the extension of the tumor that is positive. 1+ HER2 staining is considered negative, 3+ is considered positive, and 2+ is considered uncertain and in need of confirmation. For this purpose, the fluorescent *in situ* hybridization (FISH) technique, which is considered the gold standard for assessing HER2neu, is used. Some authors feel that FISH should be used in all patients, as immunohistochemistry may be deceiving: approximately 10% of patients with a tumor negative at

immunohistochemistry are FISH positive and 10% of those with positive immunohistochemistry are FISH negative. The high cost has so far prevented this approach.

The degree of staging necessary at diagnosis is controversial. Immediate staging is conducted if the patients has a locally advanced lesion (stage IIIB or C) or has serious symptoms, such as bone pain, headache, or dyspnea, in which case the imaging of the affected organ is indicated. In the majority of cases staging is delayed until after the initial surgery and is limited to those individuals who have more than three lymph nodes involved, as in all other cases the probability of detecting asymptomatic metastases is low.

The most practical way to conduct the staging may be positron emission tomography (PET) scan, followed by imaging of the organs that are abnormal on PET.

Radioactive bone scan is the most sensitive test to investigate the presence of bony metastases. When doubt persists over whether a positive bone scan indicates bony metastases or inflammatory disease of the joint, other imaging techniques, such as regular radiographs of the bones or MRI, should confirm the presence of metastases. A radiograph of the bones should be obtained every time that a bone scan is positive in the long bones; patients should be referred to an orthopedic surgeon for consideration of surgical stabilization of osteolytic metastases. Metastases to the vertebrae associated with new bone pain should be investigated immediately with an MRI to rule out spinal cord compression.

A number of circulating tumor markers, including the CEA, the CA 15-3, and the CA 27-29, may reflect the course of the tumor. The proper use of these markers is controversial, and most treatment guidelines discourage their use. They may be helpful in patients with multiple metastases undergoing systemic treatment to avoid the discomfort and the cost of repeated imaging, as long as it has been demonstrated that the markers do indeed reflect the progression or the regression of the tumor.

Treatment of Breast Cancer: General Considerations

The treatment of breast cancer varies with the stage of the disease. As for the majority of tumors, the treatment may be local and systemic. After reviewing the various forms of treatment available, a brief description of how these treatments are applied at different stages is provided and the special issues related to the management of the older woman are discussed.

It may be useful at this point to explain the nomenclature that characterizes different forms of treatment:

- Primary treatment is the most important form of treatment: for example, the primary treatment for stage I or II breast cancer is surgery; for stages IIIC and IV, it is systemic treatment.
- Adjuvant treatment, from the Latin *adjuvare,* to help, is treatment given to help the primary treatment succeed. Adjuvant radiotherapy after mastectomy may be used to prevent local recurrences; adjuvant hormonal therapy or chemotherapy may be used to prevent systemic recurrences.
- Neoadjuvant treatment refers to treatment given prior to primary treatment, with different goals, including to reduce the size of the primary tumor and to allow partial mastectomy and organ preservation, as well as to assess the responsiveness of the tumor to systemic treatment and thus establish whether it may be effective as adjuvant.
- Palliative treatment is used exclusively for symptom management, but it should be emphasized that symptom control may also prolong life.

Surgical Treatment of Breast Cancer

Surgical treatment involves mastectomy and axillary lymph node dissection. The radical mastectomy has all but been abandoned and is only used in special circumstances, such as an aggressive tumor involving the pectoral muscles. The modified radical mastectomy, which spares the pectoral muscles, has been replaced in perhaps the majority of cases by a partial mastectomy, which allows preservation of the breast. To prevent the risk of local recurrence, partial mastectomy is generally followed by breast irradiation. Breast reconstruction after modified radical mastectomy represents an alternative to breast preservation.

Axillary lymphadenectomy is associated with long-term complications, including lymphedema and peripheral neuropathy, that may compromise the function of the upper extremities. Since the development of the sentinel lymph node mapping, a complete lymphadenectomy is now required in a minority of cases (approximately 15%).

Lymph node mapping consists of the injection of a supra-vital dye or a radioactive tracer around the tumor, which allows the detection of the first lymph nodes (sentinels) where the tumor lymphatics drain. The sentinel lymph nodes are biopsied, and if they are free of tumors no further surgery is necessary. This practice has now been widely accepted and has markedly reduced the long-term morbidity of

axillary lymphadenectomy. Areas of controversy include the reliability of negative sentinel lymph nodes when the primary tumor has a diameter ≥ 3 cm, and the need to perform a full axillary dissection when the sentinel lymph nodes are microscopically free of tumors, but contain tumor cells recognizable by immunostains for cytokeratin.

Surgery may also be used for the management of metastases, especially single metastases to the brain, and more rarely to the bones, the liver, or the lung. Surgical removal of solitary brain metastases followed by radiation therapy was associated with a more prolonged survival than radiation therapy alone. New techniques including radiosurgery or the use of ultrasounds have largely superseded the surgical management of brain metastases.

Another important surgical intervention involves fixation of lytic bony lesions in long bones, to prevent pathological fractures.

Radiation Therapy

Radiation therapy is used after partial mastectomy and occasionally after modified radical mastectomy to prevent local recurrences. The conditions in which radiation therapy is indicated after mastectomy include a tumor with a diameter ≥ 5 cm, involvement of more than four axillary lymph nodes, extracapsular extension of the tumor in the lymph nodes, and invasion of the chest wall. Ongoing studies explore the use of brachytherapy (radioactive implants) or high-dose intraoperative radiation therapy in lieu of standard external beam irradiation after partial mastectomy. These approaches would prevent the need for daily irradiation for 5 weeks following surgery.

Radiation therapy is invaluable for the symptomatic management of metastases, especially painful bone metastases and brain metastases. One of the problems related to symptomatic management of bone metastases is that painful lesions are generally multiple. In this case the intravenous administration of radioisotopes such as strontium or sumerium may provide prolonged pain relief.

A new radiation technique, called radiosurgery, is commonly used for the management of brain metastases and occasionally of metastases to other organs. Radiosurgery consists of concentrating on the tumors radiation beams coming from several different sources, and in the case of brain metastases appears as effective as standard surgery.

Systemic Treatment

Table 2 illustrates different forms of systemic treatment of breast cancer.

Hormonal Treatment Hormonal treatment has been the mainstay systemic treatment of breast cancer, both in the metastatic and in the adjuvant setting. The aim of hormonal treatment is to eliminate the estrogenic effects on the tumor by antagonizing the estrogen at the receptor level (SERMs, estrogen in high doses), by offsetting the effects of estrogen (progestins, androgens), or by inhibiting the synthesis of estrogen (aromatase inhibitors). Recently, the aromatase inhibitors have become the frontline hormonal treatment for postmenopausal breast cancer, in lieu of the partial estrogen antagonists. The aromatase inhibitors appear more effective, especially because they are also effective in two conditions where the SERMs appear to lose their efficacy: low concentration of hormone receptors and overexpression of HER2/neu. The aromatase inhibitors may also be safer than tamoxifen and toremifene, in that they do not cause endometrial cancer and have lower incidence of deep vein thrombosis; however, they cause bone loss and may increase cholesterol levels. In general, it is recommended to check the patient's bone density at the beginning of treatment and every 2 years thereafter and to institute bisphosphonate therapy for severe osteopenia and osteoporosis. The value of monitoring cholesterol levels is controversial. The activity of the three available agents appears equivalent. The chemical structure of examestane is steroidal while the other two drugs are nonsteroidals. This may be the reason why these agents are not completely cross-resistant. In a small number of patients hot flushes and arthralgia and myalgia may be disabling. Hot flushes are relieved by serotonin receptor agonist antidepressant, and myalgia may respond to vitamin D. The role of the pure estrogen antagonist faslodex is not clear. This drug seems to be as effective as the aromatase inhibitors, but experience with this agent is limited. The main advantage of faslodex is monthly intramuscular administration that may be more convenient and less costly than aromatase inhibitors for patients whose oral medications are not covered by a third-party payer.

Estrogen in high doses and androgens are seldom used; they may be indicated in patients who have failed other hormonal treatments and who do not wish to receive chemotherapy.

Cytotoxic Chemotherapy Cytotoxic chemotherapy is used in patients with hormone receptor-poor tumors, in those whose tumor has not responded to previous hormonal therapy, and in those with life-threatening metastases, such as lymphangitic spread to the lung. Cytotoxic chemotherapy destroys proliferating cells, and for this reason myelosuppression, mucositis, and alopecia are common complications.

Table 2 Systemic treatment of breast cancer

Form of treatment	*Common side effects*	*Other important complications*
1. Hormonal Treatment		
Selective estrogen receptor modulators (SERMs)		
Partial antagonists		
• Tamoxifen • Toremifene	Hot flushes, vaginal secretions, dysuria, myalgia, arthralgia	Endometrial cancer, deep vein thrombosis, cerebro-vascular ischemia, hypercalcemia
Full antagonist		
• Faslodex	Hot flushes, vaginal secretions, dysuria, myalgia, arthralgia	Osteoporosis?
Aromatase inhibitors		
• Anastrazole • Letrozole • Examestane	Hot flushes, vaginal dryness, dysuria, myalgia, arthralgia	Osteoporosis Hypercholesterolemia Coronary artery disease?
Progestins	Weight gain, fluid retention	Deep vein thrombosis
Estrogen high doses	Fluid retention, congestive heart failure, coronary artery disease, deep vein thrombosis	
Androgens	Hirsutism, hair line recession, deepened voice, acne, increased libido	
2. Cytotoxic Chemotherapy	Myelosuppression, nausea and vomiting, mucositis, alopecia	
Anthracyclines		
• Doxorubicin • Epirubicin • Pegylated liposomal doxorubicin (Doxil, Caelyx)		Cardiomyopathy and congestive heart failure Hand and foot syndrome Cardiomyopathy (very rare)
Taxanes		
• Paclitaxel • Docetaxel		Peripheral neuropathy, anaphylaxis Fluid retention
Fluorinated pyrimidines		
• Capecitabine • Fluoro-uracil		Hand and foot syndrome Mucositis
Alkylating agents		
• Cyclophosphamide		Hemorrhagic cystitis, secondary malignancy
Alkaloids		
• Navelbine • Vinblastin		Peripheral neuropathy
Gemcitabine		
Platinum derivatives		
• Cisplatin Carboplatin		Renal insufficiency, peripheral neuropathy
3. Targeted Therapy		
• Trastuzumab (monoclonal antibody against HER2/neu)	Anaphylaxis	Cardiomyopathy, congestive heart failure
• Bevacizumab (monoclonal antibody against vascular endothelial growth factor)	Anaphylaxis, hypertension, bleeding	Visceral perforation

The majority of drugs also stimulate the chemoreceptor trigger zone of the medulla and cause nausea and vomiting.

A number of pharmacological changes make older individuals more susceptible to the toxicity of chemotherapy, including reduced kidney function and decreased functional reserve of normal organs and systems, in particular the hemopoietic system, the mucosas, the peripheral and central nervous system, and the myocardium. The risk and mortality of neutropenic infections as well as the risk of anemia, mucositis, peripheral and central neurotoxicity, and cardiomyopathy increase with age. Anemia is detrimental to the older person in more than one way: it is associated with increased drug-related toxicity and with fatigue that may lead to functional dependence Aware of these pharmacological changes, that National Cancer Center Network (NCCN) has issued some guidelines for the management of older patients with cancer (**Table 3**).

Of particular concern to the older cancer patient are some drug-specific complications that include the following:

- Cardiomyopathy and congestive heart failure from anthracyclines, whose incidence increases with age. Because anthracyclines are among the most active drugs in breast cancer, the prevention of this complication is of special concern. Preventive strategies include combination of doxorubicin and dexrazoxane, a chelating agent, that prevents the formation of free radicals, administration of doxorubicin by continuous infusion or low weekly doses, and substitution of pegylated liposomal doxorubicin (Doxil) for doxorubicin. Other advantages of Doxil include very mild toxicity, with low incidence of alopecia, nausea and vomiting, and fatigue, and for this reason, for some it is the anthracycline of choice in metastatic breast cancer.
- Peripheral neuropathy from paclitaxel, cisplatin, and vinca alkaloid. No effective antagonist exists for this complication. Weekly use of paclitaxel, or substitution of docetaxel for paclitaxel may reduce the risk of neuropathy.
- Mucositis is particularly common and severe with fluorinated pyrimidines (fluoro-uracil, FU). The substitution of intravenous FU with oral capecitabine may obviate this complication. Capecitabine is a pro-drug that is activated directly in the tumor, with the advantage of increased antineoplastic activity and sparing of normal tissues. Together with the anthracyclines and the taxanes, capecitabine is one of the most active antineoplastic drugs in breast cancer and is particularly suitable for older individuals, as the oral formulation allows home administration and dose titration.

Targeted Treatment Targeted treatment indicates treatment aimed at some specific component of cancer. Two monoclonal antibodies, trastuzumab and bevacizumab, directed to HER2/neu and to the vascular endothelial growth factor receptor, respectively, are available for the treatment of breast cancer. Trastuzumab is active only in HER2 overexpressing tumors and may be combined with taxanes or platinum and taxanes. The combination of trastuzumab with anthracyclines has resulted in severe cardiac toxicity, and is currently not recommended. Bevacizumab is ineffective as a single agent but is synergistic with paclitaxel.

Treatment of Breast Cancer: Specific Stage-Related Treatment

Carcinoma in Situ

The treatment of DCIS consists of total mastectomy or partial mastectomy followed by postoperative radiation therapy. When breast preservation is selected, the patient should also receive tamoxifen for 5 years to reduce the risk of local recurrence and invasive recurrence.

LCIS is generally not excised after biopsy. This tumor is generally bilateral, and the chances of a local recurrence are as high, as is the chance of recurrence in the contralateral breast. For this reason some authors recommend bilateral mastectomy. The most common approach is local excision followed by 5 years of tamoxifen.

Table 3 NCCN guidelines for the management of older individuals with chemotherapy

1. Drug doses should be adjusted to the creatinine clearance in individuals aged 65 and older.
2. Prophylactic filgrastim and peg-filgrastim should be used in patients aged 65 and older receiving moderately toxic chemotherapy (adriamycin-cyclophosphamide or adriamycin taxotere) for breast cancer.
3. Hemoglobin levels should be maintained at 12 g/dl or higher.
4. Whenever possible, one should substitute capecitabine for fluorinated pyrimidines and pegylated liposomal doxorubicin for doxorubicin.
5. Some drugs, such as taxanes in low doses, pegylated liposomal doxorubicin, capecitabine, vinorelbine, and gemcitabine, may effectively palliate the symptoms of cancer in frail individuals.

Paget's disease of the breast generally is treated with local excision and radiation.

Early Disease (Stages I–II)

The treatment of early disease generally consists of partial or total mastectomy, lymph node mapping, and full dissection if the sentinel lymph node is involved by the tumor, postoperative irradiation if breast preservation is elected, and adjuvant treatment. Postoperative irradiation to the axilla is administered if more than four lymph nodes are involved by the tumor and/or if there is spilling of the tumor outside the lymph node capsule. Adjuvant treatment is determined by the concentration of hormone receptors and by the involvement of axillary lymph nodes. **Figure 1** illustrates the choice of treatment according to the tumor characteristics.

In postmenopausal women an aromatase inhibitor is currently considered the adjuvant hormonal treatment of choice. Ongoing studies are exploringa the possibility that at least in some patients at low risk of recurrence, sequential treatment with a SERM followed by an aromatase inhibitor may be more effective than the aromatase inhibitor alone. Other studies are exploring the possibility of preventing the aromatase inhibitor-induced osteoporosis with zolendronate, an intravenous bisphosphonate.

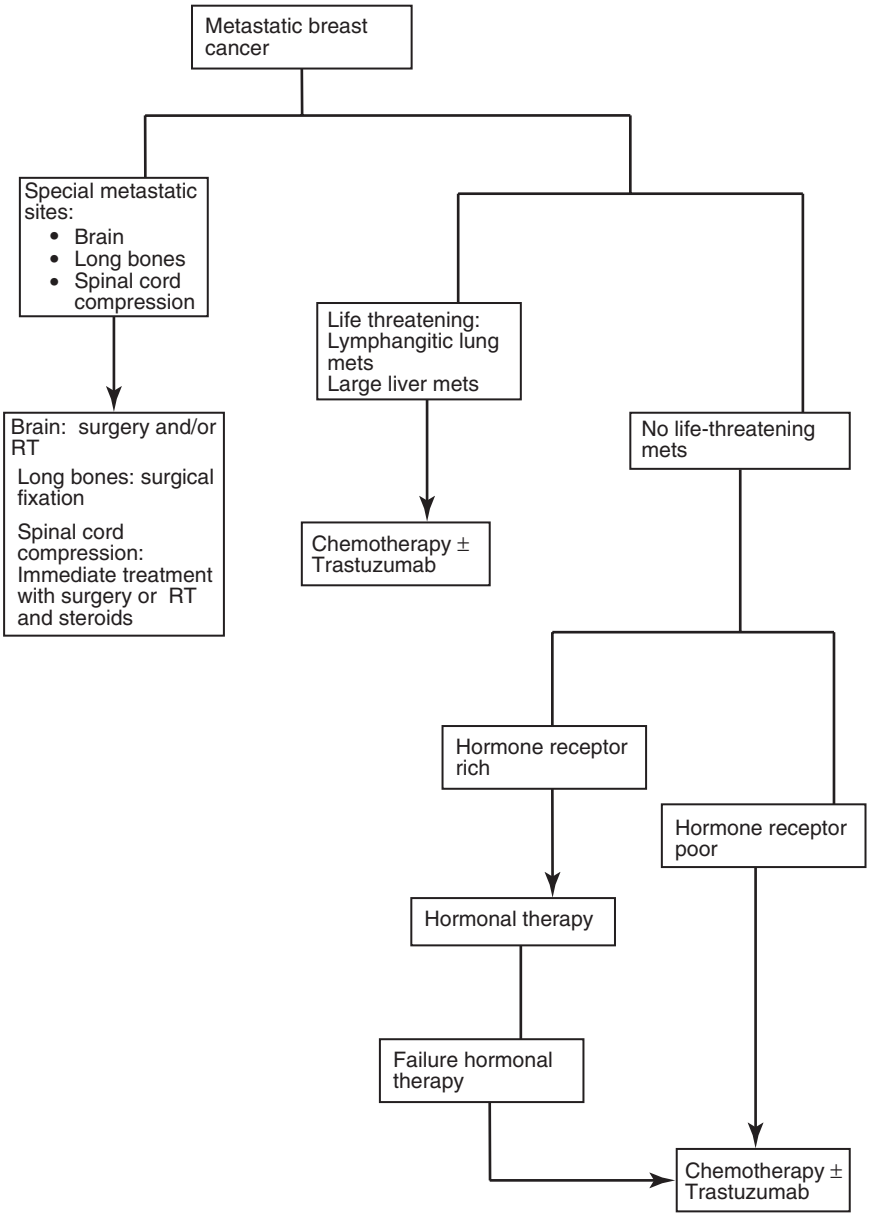

Figure 1 Choice of breast cancer treatment according to the tumor characteristics.

Three recent and yet unpublished studies report that the addition of trastuzumab for 1 year after chemotherapy reduced by more than 50% the risk of systemic recurrence of HER2/neu overexpressing tumors.

Finally, neoadjuvant chemotherapy or hormonal therapy may be occasionally used in these patients to reduce the tumor size and allow breast preservation.

There are a number of age-related controversies in the management of early stage breast cancer:

- Could early breast cancer be managed with hormonal therapy only and without surgery in older women? At least two randomized controlled studies showed that surgery followed by tamoxifen produced a better survival than tamoxifen alone in woman age 70 and over. It is certainly possible that the aromatase inhibitors prove more effective than tamoxifen, but it is not clear whether one more study of this issue is necessary. Mastectomy, even total mastectomy, may be performed under local anesthesia, with minimal risk of complications or quality of life compromise. The benefits of a nonsurgical approach appear negligible or even non-existent.

- Could postoperative radiation therapy be avoided in patients undergoing breast preservation? It is clear that the risk of local tumor recurrence declines with age, and for women over 65 with small tumors (diameter of 1 cm or less), the risk is probably less than 3% at 5 years in the absence of radiation and less than 1% with radiation. The patient may then decide whether this small risk of recurrence is worth the inconvenience and the toxicity (minimal) of the treatment. If brachytherapy or intraoperative irradiation prove effective, this issue of convenience may become irrelevant.

- When is adjuvant therapy indicated? An ongoing meta-analysis of all randomized studies of adjuvant treatment of breast cancer has clearly demonstrated that adjuvant hormonal therapy with tamoxifen (and presumably with aromatase inhibitors) reduces the risk of recurrence of breast cancer by 50% in women of all ages. The benefits of adjuvant chemotherapy instead decline with age and are not apparent after age 70. This is partly due to the small sample size (women over 70 represented 3% of all

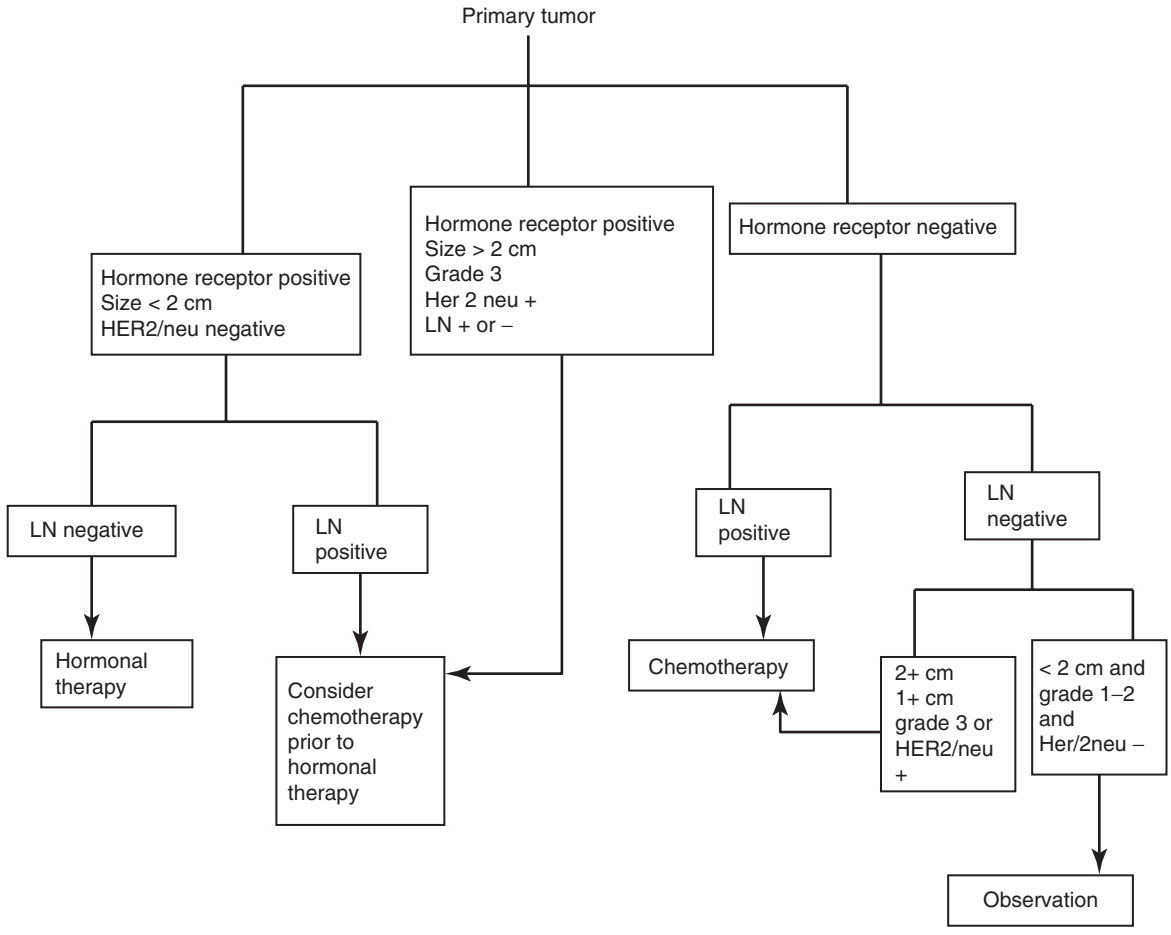

Figure 2 Treatment of metastatic disease.

women included in chemotherapy trials). It is also possible that chemotherapy is less effective in this group of patients with more indolent tumors. Based on current evidence, it seems unreasonable to consider the breast cancer of 70-year-olds different from that of all other postmenopausal women for whom adjuvant chemotherapy is beneficial. A more sensible approach it is to calculate what the effective benefit of chemotherapy is in individual situations based on tumor aggressiveness and life expectancy. This estimate is obtainable with a free online program.

Locally Advanced Disease (Stage III)

In locally advanced disease the initial treatment is systemic (chemotherapy or hormonal therapy for hormone receptor-rich tumors), followed by surgery for stage IIB–IIIA tumors. The benefits of surgery for stage IIIB tumors is controversial. Radiation of the chest wall is always indicated, and radiation of the axilla should be administered for more than four lymph nodes involved by the tumor.

Metastatic Disease (Stage IV)

The treatment of metastatic disease is outlined in **Figure 2**.

As chemotherapy or hormonal therapy does not penetrate the brain in therapeutic concentrations, brain metastases should be resected, when feasible, or irradiated. Stereotactic radiosurgery is now used in the majority of cases in lieu of surgical resection.

Lytic metastases to the long bones, especially to the femur and the humerus, are susceptible to pathological fracture and need surgical stabilization. Spinal cord compression is an oncological emergency requiring immediate treatment to prevent paralysis and incontinence. When only one area of the spine is involved, surgical decompression is the treatment of choice; otherwise, the patient should receive radiation therapy and steroids in high doses.

When the disease is life-threatening, chemotherapy is the treatment of choice, as it acts more rapidly than hormonal therapy.

The choice of hormonal therapy depends on whether the patient has received or is receiving adjuvant hormonal treatment. Clearly, if the metastases occurred while the patient was receiving adjuvant hormonal treatment or shortly (2 years) after completion of adjuvant treatment, an alternative form of hormonal therapy is indicated.

It is also important to add that patients with bone metastases benefit from intravenous bisphosphonates (pamidronate or zolendronate) in addition to their systemic treatment. These agents delay the progression of bony metastases and reduce pain and the risk of bony complications (including fractures and need for palliative irradiation).

Conclusions

The risk of breast cancer increases with age, at least until age 80. Currently 50% of all breast cancer occurs in women ages 65 and over, and this percentage is expected to increase with the aging of the population.

The screening of asymptomatic women for breast cancer reduces the risk of cancer-related mortality and should be continued in all women with a life expectancy of at least 5 years, irrespective of age. The benefits of chemoprevention of breast cancer in older women are not established, with the exception of women at very high risk. It is possible that common medications of widespread use, such as cholesterol-lowering statins or NSAIDs, may also lower the incidence of breast cancer.

The principles of breast cancer treatment do not change with age. However, in older women, postoperative radiotherapy after partial mastectomy may not be necessary; adjuvant chemotherapy should be used only in women in whom it may produce a reduction in mortality; and the toxicity of chemotherapy may be increased. The NCCN guidelines for the management of cancer in older patients may help ameliorate the complications of chemotherapy.

See also: Cancer and Age; Diet and Nutrition.

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Cardiovascular System

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Glossary

Afterload – The resistance to ejection of blood by the left ventricle.

Arterial Compliance – The distensibility of the arterial wall.

Atherosclerotic Vascular Disease – A disorder affecting medium and large arteries in which the subintimal deposits of lipids and connective tissue cause a reduction or an obstruction of blood flow through the arteries. This disorder may cause coronary artery disease, peripheral arterial disease, carotid arterial disease, cerebrovascular disease, and abdominal aortic aneurysm.

Contractility – The intrinsic ability of the heart to generate force.

Heart Failure – A disorder in which the cardiac output is not adequate to meet the metabolic needs of the tissues despite an adequate left ventricular filling pressure.

Hypertension – An increase in blood pressure.

Peripheral Vascular Resistance – Measured by dividing mean arterial pressure by cardiac output.

Preload – The filling volume of the left ventricle.

Introduction

Age-related changes in the cardiovascular system, overt and occult cardiovascular disease, and decreased physical activity affect cardiovascular function in the elderly. With aging, there is a loss of myocytes in both the left and right ventricles, with a progressive increase in myocyte cell volume per nucleus in both ventricles. With aging, there is an increase in intimal media thickness and endothelial dysfunction accompanied by both luminal dilatation and a decrease in arterial compliance or distensibility, with an increase in vascular stiffness. Increased vascular stiffness is an independent predictor of hypertension, atherosclerosis, cardiovascular events, and mortality in elderly persons. With aging, there is a progressive reduction in the number of pacemaker cells in the sinus node, with 10% of the number of cells present at age 20 remaining at age 75. With aging, there is also an increase in the prevalence and complexity of supraventricular and ventricular arrhythmias and an increase in the prevalence of left and right bundle branch block.

Afterload

Afterload is the resistance to ejection of blood by the left ventricle. Afterload is composed of two components: (1) peripheral vascular resistance, which is the steady-state component and the opposition to steady blood flow, and (2) characteristic aortic impedance, which is the dynamic component and the opposition to pulsatile blood flow. Peripheral vascular resistance is measured by dividing mean arterial pressure by cardiac output and is inversely proportional to the cross-sectional area of the peripheral vascular beds. Characteristic aortic impedance is measured as the time variation in mean arterial pressure/flow through the aorta and is inversely proportional to the arterial compliance (the distensibility of the arterial wall). An indirect measurement of afterload is the pulse wave velocity, which measures the propagation speed of pressure waves traveling from proximal to distal arterial segments and which increases as arteries become less compliant.

With aging, the large elastic arteries become dilated with a decrease in compliance. Progressive

thickening of the aortic media and intima are associated with aortic enlargement. There is an age-associated increase in arterial stiffness caused by changes in the arterial media such as thickening of the smooth muscle layers, increased fragmentation of elastin, an increase in the amount and characteristics of collagen, and increased calcification. These structural changes are associated with a decrease in aortic distensibility due to increased aortic stiffness with an increase in pulse wave velocity. These structural changes in the arterial wall are independent of coexisting atherosclerosis. An increase in pulse wave velocity with age has been found in a population with a low prevalence of atherosclerosis. The age-associated increase in stiffness and reduction in distensibility of large elastic arteries are not observed in distal arteries.

Impedance spectral patterns have demonstrated an age-related increase in characteristic aortic impedance and in peripheral vascular resistance. The decrease in arterial compliance contributes more to the age-related increase in afterload than does the loss of peripheral vascular beds. Peripheral vascular resistance is not age related in older persons without clinical or occult coronary artery disease but increases with age in persons with coronary artery disease. Arterial stiffening appears as an increase in pulse wave velocity and is associated with degeneration of the vascular media independent of atherosclerosis. Arterial stiffening causes earlier occurrence of wave reflection from peripheral sites to the ascending aorta during left ventricular ejection. Therefore, aortic and carotid phasic pressures increase to a greater magnitude at a later time during left ventricular ejection, causing an increase in systolic and pulse pressures and a delayed peak in the aortic pressure pulse contour.

Circulating levels of catecholamines increase with age, especially with stress. However, β-adrenergic vasodilation of vascular smooth muscle is decreased with aging. α-Adrenergic vasoconstriction of vascular smooth muscle is not changed with aging. The impaired vasodilator response to β-adrenergic stimulation with age is most important during exercise and contributes to the increased afterload associated with aging.

Increased afterload causes an increase in blood pressure. With aging, there is an increase in systolic blood pressure and a widened pulse pressure. A slight decrease in diastolic blood pressure occurs after the sixth decade. The increase in systolic blood pressure is due to interactions of aging, cardiovascular disease, and lifestyle factors such as dietary sodium intake, level of physical activity, and body weight. An age-associated increase in the index of aortic stiffening is not found in normotensive persons on a low sodium chloride diet. The increase in carotid augmentation index (which is an index of aortic stiffening) in highly trained elderly men is one-half of that expected on the basis of age alone.

As aortic compliance is reduced with aging, the transfer of kinetic energy from the blood ejected during left ventricular systole to potential energy stored in the elasticity of the aortic wall is reduced. Consequently, the return of the potential energy stored in the elasticity of the aortic wall back to the kinetic energy of blood flow during diastole is also reduced. Therefore, the left ventricle must eject its stroke volume into a less compliant aorta with greater pressure and force to achieve an adequate cardiac output. The increased pulse wave velocity also causes the pressure in the aorta to increase and peak later in systole, contributing to the increased systolic blood pressure and widened pulse pressure.

Posterior left ventricular wall thickness increases with increasing age in normotensive men and women without coronary artery disease. The increase in left ventricular wall thickness associated with aging is mediated by an increase in systolic blood pressure. Aging is also associated with an increase in the prevalence of hypertension and cardiovascular disease. Therefore, the prevalence of echocardiographic left ventricular hypertrophy increases with age.

Age-associated left ventricular hypertrophy is caused by an increase in the volume but not in the number of cardiac myocytes. Fibroblasts undergo hyperplasia, and collagen is deposited in the myocardial interstitium. Increased afterload increases left ventricular systolic stress with the addition of sarcomeres in parallel. This causes increased left ventricular wall thickness with a normal or reduced left ventricular wall thickness.

It was reported in 2001 that echocardiographic left ventricular hypertrophy was present in 44% of 1881 women, mean age 81 years, and in 43% of 924 men, mean age 80 years. Echocardiographic left ventricular hypertrophy was present in 72% of hypertensive Blacks, in 56% of hypertensive Whites, and in 53% of hypertensive Hispanics. However, echocardiographic left ventricular hypertrophy was present in only 2% of elderly persons without hypertension or overt cardiac disease.

Regular aerobic endurance exercise attenuates age-related reductions in central arterial compliance and restores levels in previously sedentary healthy middle-aged and elderly men. Regular aerobic endurance exercise also can prevent the age-associated loss in endothelium-dependent vasodilation and restore levels in previously sedentary middle-aged and elderly healthy men. These are mechanisms by which regular

aerobic endurance exercise contributes to a decreased risk of cardiovascular disease in the elderly.

Preload

Preload is the filling volume of the left ventricle. Preload is determined by numerous factors that influence blood return to the heart and by the mechanical properties of the heart during diastolic filling of the left ventricle.

Resting left ventricular end-diastolic volume is not age related in healthy persons, indicating that resting preload does not change with age. However, although resting preload does not change with age, left ventricular early diastolic filling decreases with aging.

Passive filling of the left ventricle occurs during the rapid filling and diastasis phases of early diastole. With aging, left ventricular stiffness is increased, left ventricular compliance is reduced, left ventricular relaxation is impaired, and left ventricular early diastolic filling is reduced. This may cause hypotension if preload is reduced. An age-related increase in systolic blood pressure also impairs left ventricular early diastolic filling, leading to hypotension if preload is decreased. Left ventricular filling during early diastole is reduced 50% from age 20 to 80.

Despite the decrease in left ventricular early diastolic filling with aging, preload is maintained because left atrial contraction becomes more vigorous to increase late diastolic filling of the left ventricle. Augmentation of left ventricular late diastolic filling prevents a reduction in left ventricular end-diastolic volume with aging. The ratio of late diastolic Doppler peak transmitral velocity (peak atrial or A wave velocity) to early diastolic Doppler peak transmitral velocity (peak rapid filling or E wave velocity) increases from approximately 0.6 at 30 years of age to 1.2 at 70 years of age. A reduction in E/A wave ratio with aging reflects a decrease in left ventricular compliance. An age-related increase in left atrial size resulting from increased wall stress due to increased left atrial pressure counteracts the effects of reduced left ventricular compliance with aging. It was reported that 38% of 1881 women, mean age 81 years, and 30% of 924 men, mean age 80 years, had echocardiographic left atrial enlargement.

In the Framingham Heart Study, age was the most powerful independent variable for left ventricular filling in healthy persons. Age was inversely associated with the E wave (peak early diastolic filling velocity) and was directly associated with the A wave (peak late diastolic filling velocity). Other independent variables contributing to a lesser degree of left ventricular filling were heart rate, PR interval measured from the electrocardiogram, gender, systolic blood pressure, and left ventricular systolic function. Increasing heart rate decreases peak early diastolic filling and increases peak late diastolic filling velocity. The PR interval on the electrocardiogram is inversely associated with peak early diastolic filling velocity. Women have slightly higher peak early diastolic filling velocities than men. Left ventricular systolic function is directly associated with peak early diastolic filling velocity. Increasing systolic blood pressure increases the peak late diastolic filling velocity.

A decrease in preload is not well tolerated in the elderly. Decreased intravascular volume, reduced venous return to the heart, vasodilation by drugs or disease states, and use of drugs such as diuretics or nitrates decrease preload and may result in reduced cardiac output and hypotension in the elderly. Reduced compliance of the left ventricle and decreased cardiac and vascular responsiveness to β-adrenergic stimulation cause the elderly to be greatly dependent on the Frank–Starling mechanism to increase cardiac output. The elderly are more susceptible to developing orthostatic hypotension. Impaired baroreceptor reflex sensitivity, reduced cardiac responsiveness to β-adrenergic stimulation, loss of arterial compliance, reduced venous return caused by increased venous distensibility, impaired compensatory mechanisms for maintenance of fluid volume and electrolyte balance, increased incidence of common precipitating diseases and disorders, and the use of multiple drugs contribute to orthostatic hypotension. Elderly persons are also more susceptible to developing postprandial hypotension.

Since left atrial contraction can contribute up to 50% of left ventricular filling in a poorly compliant left ventricle, development of atrial fibrillation may result in marked decrease in cardiac output because of the loss of left atrial contribution to left ventricular late diastolic filling. A fast ventricular rate associated with atrial fibrillation will also decrease the time for diastolic filling of the left ventricle.

The incidence of chronic atrial fibrillation also increases with age. According to one report, chronic atrial fibrillation was present in 16% of 1160 men, mean age 80 years, and in 13% of 2464 women, mean age 81 years. The prevalence of chronic atrial fibrillation was 5% in persons aged 60 to 70 years, 13 to 14% in persons aged 71 to 90 years, and 22% in persons older than 90 years.

Cardiac output is increased during exercise in healthy elderly persons by an increase in venous return to the heart, increasing diastolic filling of the left ventricle, and allowing an increased stroke volume to be ejected during exercise. This is the Frank–Starling mechanism. In healthy persons in the Baltimore

Longitudinal Study of Aging, the maximal heart rate response to exercise was reduced with age. However, exercise stroke volume increased with age to maintain the exercise cardiac output. The increase in exercise stroke volume resulted from an increase in left ventricular end-diastolic volume (preload) by the Frank–Starling mechanism. In contrast, healthy non-elderly persons achieved an increase in exercise cardiac output primarily by an increase in heart rate. Exercise stroke volume increased in non-elderly healthy persons by a slight increase in left ventricular end-diastolic volume and by a large reduction in left ventricular end-systolic volume. The exercise-induced increase in heart rate and decrease in left ventricular end-systolic volume in non-elderly persons are probably mediated by β-adrenergic stimulation. The increase in left ventricular end-diastolic volume during exercise in healthy elderly persons suggests that the age-associated decrease in resting left ventricular early diastolic filling does not persist during exercise.

Contractility

The intrinsic ability of the heart to generate force does not change with age in healthy persons. However, the duration of contraction and relaxation is prolonged in senescent animals. Prolongation of left ventricular ejection time and of the pre-ejection period with aging in healthy persons indicates that prolongation of contraction occurs with aging. Prolongation of the duration of contraction in senescent animals is associated with increased muscle stiffness and with prolongation of the action potential duration. These age-related changes are associated with cellular changes in the excitation–contraction coupling mechanism and may be an adaptive response to preserve contractile function in response to an age-induced increase in afterload.

There is no reduction of resting left ventricular ejection fraction or circumferential fiber shortening in elderly persons without heart disease. Systolic function with exercise is impaired with aging. In the Baltimore Longitudinal Study of Aging, elderly persons showed less of an exercise-induced increase in left ventricular ejection fraction than did younger persons because of an age-related increase in left ventricular end-systolic volume. However, absolute values of left ventricular ejection fraction at maximal exercise in healthy elderly persons rarely decreased from basal values. Age-associated decreases in maximal heart rate and in left ventricular contractility during maximal exercise are manifestations of reduced β-adrenergic responsiveness with aging partially offset by exercise-induced left ventricular dilation.

Diastolic Function

Aging is associated with prolongation of isovolumic relaxation time, a reduction in early diastolic filling of the left ventricle, and augmentation of left ventricular late diastolic filling. Normal aging changes affecting left ventricular diastolic function include an increase in systolic blood pressure, an increase in left ventricular wall thickness, a reduction in left ventricular early diastolic filling, prolongation of left ventricular diastolic relaxation, an increase in left atrial size, and an increase in left ventricular late diastolic filling.

With aging, there occurs a slowing of the rate at which calcium is sequestered by the sarcoplasmic reticulum following myocardial excitation, which results in reduced left ventricular relaxation. Accumulation of calcium at the onset of diastole may impair left ventricular diastolic relaxation and early diastolic filling. Decreased oxidative phosphorylation and cumulative mitochondrial peroxidation occurring with aging may also impair left ventricular diastolic function.

Increased left ventricular stiffness with aging due to increased interstitial fibrosis and cross-linking of collagen in the heart impairs left ventricular diastolic relaxation and filling. Myocardial ischemia in the absence of coronary artery disease may be caused by decreases in capillary density, and coronary reserve with aging further impairs left ventricular diastolic function in the elderly.

In addition to a decrease in left ventricular diastolic relaxation and early diastolic filling caused by aging, elderly persons are more likely to have left ventricular diastolic dysfunction because they have an increased prevalence of hypertension, myocardial ischemia due to coronary artery disease, and left ventricular hypertrophy due to hypertension, valvular aortic stenosis, coronary artery disease, hypertrophic cardiomyopathy, and other cardiac disorders. The increased stiffness of the left ventricle and prolonged left ventricular relaxation time impair left ventricular early diastolic filling and cause higher left ventricular end-diastolic pressures at rest and during exercise in older persons.

In congestive heart failure associated with left ventricular systolic dysfunction, the left ventricular ejection fraction is less than 50%. There is a reduced amount of myocardial fiber shortening, the stroke volume is decreased, the left ventricle is dilated, and the patient is symptomatic.

In congestive heart failure due to left ventricular diastolic dysfunction with normal left ventricular systolic function, the left ventricular ejection fraction is normal. Persons with congestive heart failure and

normal left ventricular systolic function but abnormal left ventricular diastolic function are unable to normally increase stroke volume, even in the presence of increased left ventricular filling pressure. Myocardial hypertrophy, ischemia, or fibrosis causes slow or incomplete left ventricular filling at normal left atrial pressures. Left atrial pressure increases to augment left ventricular filling, resulting in pulmonary and systemic venous congestion. The development of atrial fibrillation may also cause a decrease in cardiac output and the development of pulmonary and systemic venous congestion, because of the loss of left atrial contribution to left ventricular late diastolic filling and reduced diastolic filling time due to a rapid ventricular rate.

The prevalence of congestive heart failure associated with left ventricular diastolic dysfunction with a normal left ventricular ejection fraction increases with age and is higher in older women than in older men. In 674 persons, mean age 81 years, with congestive heart failure, a normal left ventricular ejection fraction was present in 44% of Black men versus 58% of Black women, in 46% of Hispanic men versus 56% of Hispanic women, in 35% of White men versus 57% of White women, and in 38% of men versus 57% of women. The Framingham Heart Study reported that 51% of 73 persons, mean age 71 years, with congestive heart failure had a normal left ventricular ejection fraction. The Cardiovascular Health Study reported that 59% of 186 persons, mean age 73 years, with congestive heart failure had a normal left ventricular ejection fraction. Left ventricular ejection fraction should be measured in all persons with congestive heart failure in order that appropriate therapy may be given. For example, calcium channel blockers should not be administered to elderly persons with congestive heart failure and an abnormal left ventricular ejection fraction. Digoxin should not be used to treat elderly persons with congestive heart failure and a normal left ventricular ejection fraction if sinus rhythm is present. By increasing contractility through increasing intracellular calcium ion concentration, digoxin may increase left ventricular stiffness, increasing left ventricular filling pressure and adversely affecting congestive heart failure due to left ventricular diastolic dysfunction. Elderly persons with congestive heart failure due to abnormal left ventricular ejection fraction tolerate higher doses of diuretics than do elderly persons with congestive heart failure and normal left ventricular ejection fraction. Elderly persons with congestive heart failure due to left ventricular diastolic dysfunction with normal left ventricular ejection fraction need high left ventricular filling pressures to maintain an adequate stroke volume and cardiac output and cannot tolerate intravascular depletion. These persons should be treated with a low-salt diet with cautious use of diuretics, rather than with large doses of diuretics.

Cardiovascular Response to Exercise

The maximal oxygen consumption (VO_{2max}) is the best overall measurement of cardiovascular fitness. VO_{2max} is the product of cardiac output and systemic arteriovenous oxygen difference at peak exercise. Maximal cardiac output is the heart rate multiplied by the stroke volume at peak exercise, and is a more direct measurement of cardiovascular reserve than is VO_{2max}. VO_{2max} is reduced with aging. The degree of decrease of VO_{2max} with aging is affected by physical conditioning, subclinical coronary artery disease, smoking, and body weight.

In the Baltimore Longitudinal Study of Aging, older male athletes had a higher peak exercise VO_{2max} than older sedentary men. The greater peak exercise VO_{2max} in older male athletes than in older sedentary men was achieved by a higher cardiac index and a greater systemic arteriovenous oxygen difference. The higher peak exercise cardiac index in older male athletes than in older sedentary men was due to a higher stroke volume index with similar maximal heart rates.

A reduction in maximal systemic arteriovenous oxygen difference occurs with aging. The decrease in muscle mass with aging may play a major role in the decrease in systemic arteriovenous oxygen difference at peak exercise and in VO_{2max} with aging.

The effect of aging upon peak upright cycle exercise was investigated in healthy sedentary men and women aged 22 to 86 years in the Baltimore Longitudinal Study of Aging. Peak cycle work rate decreased with aging in both men and women but was greater in men than in women at any age. Both men and women had, at peak exercise, reductions in heart rate, cardiac index, and left ventricular ejection fraction and increases in left ventricular end-diastolic volume index and end-systolic volume index with aging. Peak exercise stroke volume index did not vary with age in either men or women. The exercise-induced decrease in left ventricular end-systolic volume index and increases in cardiac index, stroke volume index, and left ventricular ejection fraction from rest were greater in older men than in older women.

Therefore, the cardiovascular responses to exercise in healthy elderly persons include the following. Maximal heart rate is reduced with aging. Exercise stroke volume is increased with aging to maintain cardiac output. Increased exercise stroke volume with aging results primarily from an increase in left

Table 1 Prevalence of some cardiovascular disorders in elderly men and women

Cardiovascular disorder	*Mean age (years)*		*Prevalence*			
	Men	*Women*	*Men*		*Women*	
			No.	*Percent*	*No.*	*Percent*
Coronary artery disease	80	81	502/1160	43	1019/2464	41
Thromboembolic stroke	80	81	370/1160	32	761/2464	31
Peripheral arterial disease	80	81	374/1160	32	637/2464	26
40 to 100% extracranial carotid arterial disease	81	81	68/425	16	213/1421	15
Congestive heart failure incidence	80	81	335/1160	29	643/2464	26
Hypertension	80	81	665/1160	57	1471/2464	60
Aortic stenosis	80	81	141/924	15	322/1881	17
Mitral annular calcium	80	81	336/924	36	985/1881	52
$\geqslant 1+$ mitral regurgitation	80	81	298/924	36	985/1881	52
$\geqslant 1+$ aortic regurgitation	80	81	282/924	31	542/1881	29
Rheumatic mitral stenosis	80	81	3/924	0.3	34/1881	2
Hypertrophic cardiomyopathy	80	81	28/924	3	80/1881	4
Chronic atrial fibrillation	80	81	181/1160	16	314/2464	13
Pacemaker rhythm	80	81	61/1160	5	125/2464	5
Abnormal ejection fraction	80	81	271/924	29	416/1881	22
Left ventricular hypertrophy	80	81	393/924	43	831/1881	44
Left atrial enlargement	80	81	278/924	30	709/1881	38
Idiopathic dilated cardiomyopathy	80	81	10/924	1	19/1881	1

Data from Aronow *et al.* (2001, 2002).

ventricular end-diastolic volume by the Frank–Starling mechanism. The reduction in muscle mass with aging plays a role in the age-associated decreases in systemic arteriovenous oxygen difference and in VO_{2max} at peak exercise. The left ventricular end-diastolic and end-systolic volumes increase during peak exercise with aging. The peak exercise left ventricular ejection fraction is reduced with aging. The exercise-induced decrease in left ventricular end-systolic volume index and increases in cardiac index, stroke volume index, and left ventricular ejection fraction from rest are greater in elderly men than in elderly women.

Cardiovascular Disease

In addition to age-related changes in cardiovascular function and deconditioning due to a sedentary lifestyle in many elderly persons, elderly persons also have a higher prevalence and incidence of cardiovascular disorders that impair cardiovascular performance than non-elderly persons. Aortic valve calcification, aortic sclerosis, and mitral annular calcification are degenerative processes, accounting for their high prevalence in elderly persons. **Table 1** lists the prevalence of some cardiovascular disorders in elderly men and in elderly women.

See also: Exercise and Physical Activity.

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Careers in Aging

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Glossary

Geriatricians – Primary care oriented physicians, initially trained in family practice or internal medicine, who gain expertise in caring for older people through completion of a geriatrics fellowship, the board certification examination, and continuing professional education related to geriatric practice.

Gerontological Specialist – Persons from numerous professions and disciplines who devote the major portion of their professional time to working with, for, or on behalf of older persons.

Gerontologist – Graduates of programs offering a bachelor's master's or doctoral degree programs in which the major field of study is gerontology or aging studies.

Gerontology Worker – Persons who work directly with older adults or indirectly on behalf of elders, but who do so without training or education specific to aging.

Introduction

Gerontology is the study of the biological, psychological, and social aspects of aging. From early beginnings in research and theory, gerontology developed into a multidisciplinary field of study and, more recently, into a professional field commonly known as the field of aging. This article identifies key factors that influenced the development of gerontology as a professional field, differentiates three categories of gerontological workers and professionals, delineates generic job roles for gerontological specialists, briefly reviews professional opportunities for gerontological specialists in several traditional fields, provides a glimpse into numerous emerging career paths, and offers recommendations necessary for further career development in the field of aging.

Key Factors in Career Path Development

Three key factors in the development of career paths in the field of aging have been the enactment of federal legislation aimed at improving the quality of life for older persons, growth in the elderly population in the United States, and the advent of gerontology and geriatric education programs in higher education.

Federal Legislation

The first legislation to open a career path in the field of aging was the Social Security Act in 1935, although Social Security Administration personnel usually are not thought of as gerontology specialists. Thirty years later, the Older Americans Act (OAA) of 1965 led to the development of an aging network through which OAA-mandated programs and services are delivered to older adults. Many professionals in the field of aging are employed in this formal aging network. Funding of OAA programs and services flows from the federal level through the Administration on Aging (AoA) to the state-level offices, bureaus, or departments on aging, where state funds may be added to meet the specific needs of a state's elders. These funds then travel into a state's network of Area Agencies on Aging (AAAs), which carry out the functions of needs assessment and funding funnels (i.e., based on the needs assessment of elders in an AAA region, AAA staff issue requests for proposals and award grants to the county and local agencies that will deliver the programs and services). The only direct service to elders generally delivered by AAA staff members is care management. Most program and services delivery is carried out at the county and local level through county or city commissions or departments on aging and other local agencies and facilities. Services delivered include information and outreach, nutrition services, in-home services, activities and leisure programs, employment and volunteerism opportunities, family support, and education about aging and aging-related issues.

Elderly Population Growth

The population of elders in the United States is growing, both in number of older adults and in the proportion of the total population. Population projections show additional increases through 2030. These actual and projected population statistics have multiple implications for the delivery of goods, programs, and services for this population segment. For example, the US Department of Labor Bureau of Statistics predicts an increased demand for occupational therapists, psychologists, physical therapists, social workers, pharmacists, and nurses who have specific education and/or training to work with older persons who are becoming more frail due to physical

conditions, mental health problems, and social service needs. It also is likely that the demand will increase for gerontology-educated professionals to work with persons who are aging well, remain active, and have needs or interests outside of the health-care realm (e.g., products, programs, and services related to advocacy and legal services; architectural services and housing; banking, insurance, and other financial management services; career training, counseling and placement; retirement planning; travel and leisure; product development; transportation).

Gerontology Education in Higher Education

Title V of the original Older Americans Act authorized grants and contracts to public agencies, organizations, and institutions, including institutions of higher education, for training that would prepare persons to carry out the programs and services specified in the act. Such training could be for already employed personnel or for persons preparing for employment in aging-related agencies and organizations. Title III provided grants for community planning, services and training of personnel for programs and centers to offer leisure time activities, as well as services related to information and referral, health, welfare, counseling, and volunteerism of older adults through civic and community services. The first director of training for Title V programs was Clark Tibbitts, a long-time advocate for the inclusion of gerontology curriculum in higher education, especially for graduate-level degree programs in fields such as public administration, recreation, and social work. Tibbitts was also receptive to the idea of degree programs in gerontology. He encouraged program development within universities to meet three career needs and objectives to which AoA assigned high priority: administration of homes for the aged and similar institutions; planning, administration, and coordination (public administration) of programs at federal, state, and community levels; and administration of multiservice senior centers, including positions for recreation specialists in aging.

Title V funding provided seed money for the development of gerontology education programs and centers across the United States; however, not all gerontology education programs in existence today began with AoA funding and some of the AoA-funded programs have not survived. Peterson et al. reported in 2004 that over 50% of US community colleges, 4-year colleges, and universities offer gerontology and/or geriatric courses, while more than 500 US institutions of higher education offer a formal gerontology program (e.g., undergraduate minor in gerontology; graduate certificate in gerontology or specialization in aging; bachelor's, master's or doctoral degree program in gerontology or aging studies). In May 2005, Derek Stepp, Director of the Association for Gerontology in Higher Education (AGHE), indicated that approximately 18 associate, 41 bachelor's, 58 master's, and 9 doctoral degree programs currently are gerontology specific. AGHE has developed standards and guidelines specific to each level and type of program, as well as a review process to help in program development and evaluation. Programs that meet or exceed the AGHE standards and guidelines are eligible for Program of Merit designation. AGHE publishes and regularly updates a *Directory of Educational Programs in Gerontology and Geriatrics*, with updated information about formal credit and postdoctoral training programs in gerontology, geriatrics, and aging studies offered by institutions of higher education in the United States and AGHE members schools in other countries.

Gerontology Workers, Gerontological Specialists, and Gerontologists

With the advent of professional education and training programs in aging studies, gerontology, and geriatrics, it is possible to categorize persons who work with and/or on behalf of older persons as gerontology workers, gerontological specialists, or gerontologists. These categories, however, are neither firmly established across the field of aging nor commonly used among those who serve older adults.

Gerontology worker refers to persons who work directly with older adults or indirectly on behalf of elders, but who do so without training or education specific to aging. For example, certified nursing assistants (CNAs) work directly with elderly clients in long-term care facilities and receive training in direct care processes, but their training does not include content related to the aging process or the elderly population.

Gerontological specialist describes persons from numerous professions and disciplines who devote the major portion of their professional time to working with, for, or on behalf of older persons. Education in gerontology or aging studies, at the associate degree level or higher, means these are professional personnel who understand the aging process and have acquired specific skills to use in working with or on behalf of elders. For many positions, graduate study at the master's or doctoral degree level is required. Gerontological specialists come from a wide array of disciplines (e.g., biology, physiology, sociology,

psychology, history, economics, political science, anthropology, philosophy, religion) and professional fields (e.g., nursing, medicine, occupational and physical therapy, speech pathology and audiology, social work, counseling, pharmacy, dietetics, long-term care administration, political science and public administration, business administration, education, recreation, housing, architecture, interior design, clothing and textiles, family studies and family therapy, journalism, advertising and marketing, music or art therapy). Gerontology is more likely a secondary field of study for gerontological specialists; they tend to major in a discipline or professional field, but also complete academic work specific and/or related to gerontology. For example, a director of social work for a county commission on aging or in a long-term care facility usually holds a degree in social work (BSW or MSW), but also may have completed an undergraduate minor or graduate certificate in gerontology. It is the college degree, plus the specialized education in gerontology, that qualifies this social worker as a gerontological specialist.

Gerontologist is a relatively new professional title that is emerging due to the advent of bachelor's, master's, and doctoral degree programs in which the major field of study is gerontology or aging studies. Technically, it is only graduates of these programs who are eligible to call themselves gerontologists; however, this title continues to be misunderstood and is often used inappropriately. Based on both their formal gerontology education and the nature of their work, gerontologists also may be seen as gerontological specialists. Without the same formal educational background, however, not all gerontological specialists are gerontologists. Since gerontologist is not yet a clearly defined designation and is not yet consistently used within the field of aging, the term gerontological specialist is used in the following discussion.

Employment Settings and Job Roles

Where do gerontological specialists work? What type of job roles do they play? In what ways and situations do they work with older adults?

Employment Settings

Although it is possible for persons with educational backgrounds in gerontology or aging studies to work in almost any setting, it is likely that most are employed in the following:

- Organizations, including professional organizations (e.g., American Society on Aging), organizations that serve specific populations of or issues for older persons (e.g., Alzheimer's Association, American Association of Homes and Services for the Aging, National Caucus and Center on Black Aged, National Hispanic Council on Aging, National Indian Council on Aging, Older Women's League), or senior citizen membership groups (e.g., AARP, Gray Panthers)
- Institutions (e.g., adult day care, assisted living, long-term care, or residential facilities; hospitals, outpatient clinics, and mental health facilities; colleges and universities; churches)
- Corporations (e.g., health-care companies, insurance companies, investment firms, retailers)
- Government agencies (e.g., county commissions, Area Agencies on Aging, state offices on aging, or National Association of Area Agencies on Aging; Social Security Administration or Medicare and Medicaid service centers; health departments; Department of Veterans Affairs; Administration on Aging or National Institute on Aging).

Job Roles

Before exploring some specific professional opportunities, it is important to consider the types of job roles carried out by professionals in the field of aging. Peterson *et al.* identified seven role categories that gerontological specialists commonly fulfill:

1. Advocacy: Professionals in the field of aging are advocates both directly for older adults (e.g., in ombudsperson roles within long-term care settings) and on behalf of older adults (e.g., through policy development, critique, and evaluation).
2. Direct service provision: Gerontological specialists determine needs, develop plans, find resources, and solve problems through their use of processes such as assessment, treatment, counseling, case management, therapy, education, and rehabilitation.
3. Education and training: Gerontological specialists plan, teach in, administer, and evaluate educational programs for and about elders through a variety of venues (e.g., older learner programs and institutes; credit-based courses and gerontology programs in colleges and universities; continuing education and community-based programs; health promotion workshops, seminars, and educational materials; staff development for personnel in agencies and facilities that serve older adults and their families).
4. Management and administration: Gerontological specialists serve as the managers and administrators

of agencies and facilities (e.g., nursing homes and other long-term care facilities; county, state, and federal program, including Area Agencies on Aging) where they assess needs and interests of elders, then develop programs and services to meet the identified needs and services. Gerontological specialists serve as administrators of educational programs and research centers in institutions of higher education.

5. Marketing and product development: As more persons live into later life in better physical and mental health, there is a need for professionals to develop products that improve quality of life for elders. There also is a growing market for products that assist elders with activities of daily living (ADLs) and instrumental activities of daily living (IADLs). Gerontological specialists work in a variety of settings as developers and consultants for new products or product improvement; they also work in advertising, marketing, and sales for these products.
6. Program planning and evaluation: Much of the work of gerontological specialists in the formal aging network is related to the design, implementation, and evaluation of programs to meet the needs of older adults. Such tasks, however, are not restricted to governmental agencies; they are also responsibilities for program administrators and staff in community-based organizations (e.g., senior centers, city recreation programs, adult and community education programs, college/university-based programs for older adults).
7. Research: The earliest gerontological specialists were researchers seeking to gain a better understanding of the processes of aging and the implication of aging for older individuals and the broader society. Research continues to be a primary role for gerontologists with doctoral level education in gerontology-specific or -related disciplines and professions. There also is a growing role for gerontological researchers in applied research.

Gerontological Specialists in Traditional Career Fields

Although an increasing number of new professionals in the field of aging have a gerontology-specific educational background, most current and future professionals come to the field with discipline- or profession-based degrees other than gerontology or aging studies. As a result, they are more likely to seek a position related to their degree that also allows them to work with or on behalf of older persons. Gerontological specialists work in an array of traditional fields, described in the following sections.

Social Work

Social work is one of the fastest growing fields that serves older adults. Social workers provide direct services to elders and their families; they also link their clients with additional programs and services to meet needs (e.g., meal programs, legal services, senior centers, visiting nurse and other in-home services, transportation systems). They consult with, counsel, and educate their elderly clients. They function as discharge planners, casework supervisors, agency and program administrators, policy developers and analysts, ombudsmen and advocates, researchers, client and staff group leaders, and family and in-service trainers. They are trained to be sensitive to population diversity (e.g., ethnic/racial background, socioeconomic status, sexual orientation, spiritual diversity). They work with elders in a variety of settings, such as adult day care centers, adult protective services, alcohol and substance abuse services, Area Agencies on Aging, assisted living facilities, bereavement services, child welfare agencies (related to grandparent caregiving and other family issues), educational institutions, elder abuse programs, employment and volunteer programs, faith-based organizations, family service organizations, home health care, hospice, hospitals or medical centers, information and referral agencies, life care communities, mental health centers, mental retardation and developmental disabilities services, nursing homes, nutrition programs, ombudsman programs, outpatient primary care settings, planning agencies, prisons, private clinical practice, private geriatric care management, protective services, public social service agencies, rehabilitation centers, research centers, respite programs, senior centers, senior housing facilities, and veterans' services. Some gerontological social workers work in non-traditional settings for social work, such as banks and investment firms; corporate eldercare and employee assistance programs; group medical, mental health, and dental practices; insurance companies; law firms and legal or paralegal services; public utilities companies; and labor unions. A baccalaureate degree (BSW) opens the door to direct service with elders in some settings; however, a master's degree (MSW) is required in most clinical settings. The Council for Social Work Education (CSWE) accredits social work degree programs; professional credentials are granted through the National Association for Social Workers (NASW). Social workers also are governed by state licensure regulations. Education about aging

and working with elderly clients is available in more than half of the existing degree programs. There is, however, a shortage of social work faculty with gerontological or geriatric expertise. To address this shortage, one component of the Geriatric Social Work Initiative (GSWI) is the Hartford Doctoral Fellows Program, administered by the Gerontological Society of America (GSA) with funding from the John A. Hartford Foundation. As many as 15 Hartford Doctoral Fellows in geriatric social work are selected each year.

Nursing

Nurses with gerontological educational backgrounds work in hospitals, nursing homes, and other long-term care settings; clinical medicine practices with physicians and other health-care professionals; geriatric assessment centers; hospice programs/facilities; visiting nurse organizations; in-home health-care programs; and other settings where older adults seek medical care. There are three levels of nursing certification that are gerontology specific:

- Associate degree/diploma level: gerontological nurse (registered nurse, certified)
- Baccalaureate level: gerontological nurse (registered nurse, board certified)
- Advanced practice level: advanced practice nurse (registered nurse, board certified) as either a clinical nurse specialist in gerontological nursing or a gerontological nurse practitioner.

Two recent initiatives are aimed at increasing the number of gerontological nurse specialists and improving the quality of gerontological nursing services offered to older adult clients. The John A. Hartford Foundation Institute for Geriatric Nursing is a nurse-led organization intent on helping to shape higher quality health care for older Americans by promoting geriatric nursing through efforts in four areas: nursing education, nursing practice, nursing research, and nursing policy. Nurse Competence in Aging (NCA) is a 5-year collaborative initiative involving the Atlantic Philanthropies (USA) Inc., the American Nurses Association (AHA) through its American Nurses Foundation (ANF), the American Nurses Credentialing Center (ANCC), and the John A. Hartford Foundation Institute for Geriatric Nursing at New York University's Division of Nursing in the Steinhardt School of Education. NCA is committed to the enhancement of geriatric activities by national specialty nursing associations, promotion of gerontological nursing certification, and provision of a web-based comprehensive geriatric nursing resource center.

Therapeutic Recreation

Until recently, the primary role of recreation therapists in practice with older adults was as activity directors in long-term care and community settings. Recently, however, the National Therapeutic Society (NTRS), a branch of the National Recreation and Park Association (NRPA), outlined new directions and trends for practice, including provision of services to medically fragile elders living at home; use of bibliotherapy to stimulate the cognitive skills of older adults; providing therapeutic recreation services to persons suffering from HCV, HIV, and substance abuse; and partnering with public agencies to provide recreational therapy to emotional and behaviorally disturbed children and their families, including family units in which grandparents or great-grandparents are raising their grandchildren. Members of NRPA's Leisure and Aging Section (LAS) work with elders in camping and outdoor experiences, travel and tourism, retirement communities, wellness programs, long-term care facilities, community recreation programs for well older adults, senior centers, and recreational programs for frail elders.

Geriatric Medicine

The American Geriatrics Society defines geriatrics as the branch of medicine that specializes in aging-related diseases and medical problems of older adults. Geriatricians are primary care-oriented physicians, initially trained in family practice or internal medicine, who gain expertise in caring for older people through completion of a geriatrics fellowship, the board certification examination, and continuing professional education related to geriatric practice. Geriatricians commonly work in interdisciplinary or multidisciplinary teams, sometimes called geriatric assessment teams. Additional team members come from related fields (e.g., other medical or surgical specialists, nurses or nurse practitioners, social workers, psychologists or psychiatrists, physician assistants, pharmacists, physical and/or occupational therapists, speech pathologists, audiologists, dietitians). Current and anticipated future shortages exist for both direct-care geriatricians and academic geriatricians to train medical residents.

Clinical Psychology and Clinical Geropsychology

Clinical, clinical work, and working clinically are terms that recognize clinical psychologists as

professional practitioners who hold a doctoral degree in psychology and, based on this degree, are licensed or certified, at the independent practice level, by the state in which they practice. Such clinicians are authorized to diagnose or assess individual clients and furnish preventive and therapeutic services. Standards for clinical psychologists are approved by the American Psychological Association (APA) and by the federal centers for Medicare and Medicaid services. The Omnibus Budget and Reconciliation Act of 1987 increased attention on and services for older adult mental health issues and expanded Medicare reimbursement for mental health conditions of older persons. In 1998, the Commission for the Recognition of Specialties and Proficiencies in Professional Psychology (CRSPP) recommended, and the APA Council of Representatives approved, recognition of clinical geropsychology as proficiency in professional psychology. Recommendations from a 1992 APA national conference on clinical training in psychology and the improvement of psychological services to older persons led to formation of the Interdivisional Task Force on Practice in Clinical Gerontology by APA Division 20: Adult Development and Aging and Section II: Clinical Geropsychology of Division 12: Society of Clinical Psychology. Charged with providing guidance for clinical practice with older adults, task force members developed guidelines related to six practice aspects: attitudes; general knowledge about adult development, aging, and older adults; ethical issues; assessment; intervention, consultation and other service provision; and education. These guidelines are now in effect through August 31, 2010. Additional support for clinical practice with elders has come through two additional venues. The California State Senate Bill 953 of 2002 requires graduate-level or continuing education coursework on aging and long-term care as a prerequisite for licensure to practice as a clinical psychologist. In 2003, Congress appropriated funding, through the Graduate Psychology Education (GPE) Program in the Health Resources and Services Administration's Bureau of Health Professions, for training in geropsychology to overcome a public health shortage in this area. In spite of these initiatives, there remains a shortage of clinical psychologists and geropsychologists to meet the needs of older persons. This shortage is partially due to inadequate education or training in geropsychology for psychology interns, externs, and practicing clinical psychologists. Further initiatives targeted at mental health issues for older adults may spur interest among current and future psychologists. For example, the funding from the Substance Abuse and Mental Health Services Administration (SAMSHA) for the Older Adult Mental Health Targeted Capacity Expansion (TCE) Grant Program is aimed at helping communities build the necessary infrastructure to provide direct services that meet the increasingly diverse mental health needs of older adults.

Rehabilitation Therapy

Rehabilitation therapy is a broad category of professions, including physical therapy, occupational therapy, speech pathology, and audiology. Although these professionals may choose to work in a gerontology- or geriatric-specific setting, most work with persons of many ages who have physical, mental, or developmental disabilities. Their older clients have suffered strokes or hip fractures; had joint replacement, cardiac, or other surgeries; experienced disabling illnesses or accidents; or been afflicted with chronic diseases (e.g., arthritis, Parkinson's disease) or dementia (e.g., Alzheimer's disease). Most frequently, rehabilitation therapists work in clinical settings such as hospitals and long-term care facilities. Most of these professions require a master's degree, and some have licensure requirements that must be met through examination and completion of a set number of years in clinical work. While some rehabilitation therapists have a gerontology education background, it is not required, nor has it been built into their professional education program at the graduate level. In 1978, however, the American Physical Therapy Association (APTA) established the concept of specialist certification programs, and certification in geriatrics is now available.

Long-Term Care and Residential Facility Administration or Management

Some gerontological specialists serve as administrators of an entire residential or long-term care facility, while others serve as the division or departmental directors or managers. They work in settings such as nursing homes, adult foster care homes, adult day care facilities or programs, retirement and continuing care retirement communities, home health-care programs, and other types of residential centers for older adults. These professionals are regulated and licensed by the state in which they work. Many have no formal preparation for the job except their experience as administrator trainees, while some work their way up the ladder from positions such as director of nursing or human resources manager. Others come to the position having completed specific short-term training programs or degrees in fields such as gerontology,

health-care administration, human resources, or personnel administration. A key professional organization for facility and residential administrators and managers is the American Association of Homes and Services for the Aging (AAHSA), which has a research institute and a center for Medicare education. More diverse housing interests of elders means that new types of public and private housing complexes are needed. Gerontological specialists with backgrounds in housing, architecture, facility planning, interior design, and business management are filling positions created by the opening of retirement communities by hotel corporations (some are located on college campuses), age-segregated residential complexes and public housing programs, and grandparent houses to house grandparents and the grandchildren they are raising.

Gerontology Education

Since the advent of gerontology and geriatric education programs in higher education starting in the late 1960s, academic faculty members have been engaged in delivering gerontology coursework and academic programs to students at community colleges, 4-year colleges, and universities. Most faculty members work from within a traditional department (e.g., biology, sociology, psychology, social work, nursing, health administration, interior design, nutrition and dietetics, human development, family studies); however, some are based in a gerontology program, department, institute, or center on aging or research center at their institution. Most have completed doctoral degrees in their discipline or professional field. It is becoming more common that they also have completed some type of formal education in gerontology or aging studies. In the future, some faculty administrators will enter academe with graduate-level gerontology-specific degrees. AGHE, the educational unit of the GSA, is a primary professional organization for gerontology educators and program administrators. GSA and AGHE co-sponsor an annual careers in aging week that encourages activities held on campuses across the country. AGHE publishes booklets and brochures on careers in aging, and works closely with Sigma Phi Epsilon, the gerontology honor society. The theme of the 2005 AGHE annual meeting and educational leadership conference was careers in aging.

Research

Perhaps the longest-standing career option in gerontology is research. Gerontological specialists are involved in the design and conduct of research on every aspect of aging. Early gerontology researchers were primarily discipline based (e.g., biology, sociology, demography, and psychology of aging), used quantitative methodology, tested various theories of aging, and added considerably to the base of knowledge on aging. Various longitudinal studies on aging, such as the Longitudinal Studies on Aging (LSOAs), a joint project of the National Institute on Aging (NIA) and the National Center on Health Statistics (NCHS), and the Duke Longitudinal Study on Aging, have combined quantitative and qualitative methodologies. Gerontology is among the first professional fields to understand the value of qualitative research, as well as other forms of research, including needs assessment, program evaluation, and treatment outcomes research. Research training is built into an increasing number of gerontology education programs; many students in gerontology study programs complete research and have the opportunity to serve as research assistants. The primary settings in which gerontology researchers work are academe, independent or governmental research centers, and medical centers, although some work in corporate and community settings. Gerontology research is funded through governmental programs, foundations, and corporations, which has created career opportunities related to grant writing, grantsmanship, and fundraising.

Emerging Career Paths in the Field of Aging

With continuing growth of the aging population, greater access to gerontology coursework or programs for students at more institutions of higher education, and integration of aging studies into more disciplines and professions, new career paths related to aging are emerging. Among these emerging aging-related career opportunities are the following.

Elder Law

In 1993, the American Bar Association (ABA) developed and adopted a set of voluntary national standards and procedures to accredit a number of specialty certification programs. The National Academy of Elder Law Attorneys (NAELA), a non-profit organization intent on developing and improving lawyer competence in the area of elder law, then founded the National Elder Law Foundation (NELF). Rules and regulations for certification of elder law attorneys were developed by NELF; applications for certification were first accepted in 1994. In February 1995, the ABA House of Delegates approved NELF as the certifying entity for the elder law specialization. For

purposes of certification, elder law is defined as legal practice in the form of counseling and representing older persons and/or their representatives in regard to the legal aspects of physical and mental health status and care, including long-term care planning; legal capacity of the older adult; surrogate decision making (e.g., guardianship and conservatorship); public benefits; estate planning, disposition, and administration; abuse, neglect, or exploitation of the older person; and legal matters related to housing, insurance, employment, retirement, and long-term care. Elder law attorneys also must be familiar with appropriate professional and non-legal services and resources, appropriate standards of professional conduct, and ethical practice. Although many law schools do not yet have elder law degree programs, an increasing number of schools do offer courses related to this specialization or integrate relevant content into existing courses. Most certified elder law attorneys are in private practice, but some are judges, law professors, and staff attorneys in corporate and medical settings. Some attorneys combine family and elder law in their practice or in consultation with public social services and aging agencies.

Financial Gerontology

Around 1990, financial gerontology began to emerge as an applied field that linked applied research, gerontology, and financial professions. In 2002, the American Institute of Financial Gerontology (AIFG) was founded, in partnership with Widener University and the American Society on Aging (ASA), to create educational programming for financial professionals who work predominantly with older individuals. AFIG currently offers two different educational programs in financial gerontology. The registered financial gerontologist (RFG) program is for practicing financial professionals (e.g., accountants/certified public accountants, insurance agents, attorneys, financial planners, reverse mortgage lenders, bank trust officers). RFG candidates complete a multidisciplinary curriculum of four core courses (the new science of wealth span planning; basic processes of aging: physical, psychological, social; serving the older client: values, ethics, and life development; and financing longevity) and two of six possible elective courses (families and aging: resources for professionals; the aging network and the long-term care service delivery system; long-term care solutions; financial preparedness for later life; and successful marketing to the 50+ consumer). These courses are scheduled to coincide with the annual joint conference of ASA and the National Council on Aging (NCOA) in the spring of each year. Candidates also take the RFG comprehensive examination, complete service learning activities, accept the RFG pledge of ethical practice, and pay dues for the Association of Registered Financial Gerontology (includes membership in ASA and in ASA's Business Forum on Aging). AIFG's other program is foundations of financial gerontology, which is designed to meet the needs and interests of non-financial professionals. This curriculum consists of three of the core courses from the RFG program. Participants are awarded a certificate of completion from AIFG and ASA.

Intergenerational Studies

One of the newest gerontology-related fields of study is intergenerational studies, which has grown out of the interest in programs and services that link older adults with youth. Generations Together at the University of Pittsburgh and Generations United have provided key leadership in this field's development. The first certificate program in this field, the continuing education certificate for intergenerational specialists, is a joint effort of Generations Together and the School of Social Work at the University of Pittsburgh. Two major steps in the development of this new field are the establishment in 2001 of the International Consortium of Intergenerational Programs (ICIP) and the publication, starting in 2003, of the *Journal of Intergenerational Relationships: Programs, Policy and Research* (JIR).

Older Drivers Rehabilitation Therapist

The Association for Driver Rehabilitation Specialists (ADED, an acronym retained from the organization's original name, Association of Driver Educators for the Disabled) certifies driver rehabilitation specialists (DRSs). A DRS is a professional who assesses the driving ability of disabled persons, then develops, implements, and coordinates driving rehabilitation services with those persons. The DRS evaluation involves clinical assessment, including a functional (on-road) evaluation, followed by communication of assessment results and recommendation of an appropriate driving status to the client. The evaluation also includes a passenger vehicle assessment, and DRSs consult with the client and relevant agencies about vehicle purchases or adaptations. While DRSs come from a variety of professional backgrounds (e.g., physical therapy, kineseotherapy, driver education, psychology), it is the field of occupational therapy that is taking leadership. The American Occupational Therapy Association (AOTA) is developing a specialty certification for driving rehabilitation, with one emphasis in older driver rehabilitation therapy. AOTA already offers continuing education

on older driver rehabilitation through online courses, workshops at AOTA conferences, and ASA web seminars.

Other Potential Professional Opportunities

New aging-specific or aging-related career paths are emerging out of an array of professional fields. Each of these appear to hold considerable promise to create new avenues for gerontological specialists and gerontologists to work with, for, or on behalf of older adults in exciting new ways.

K-12 Curriculum and Teacher Education Infusion of aging education into the K-12 curriculum has received considerable support over the past 10–20 years, most notably through integration of aging content into existing courses or development of aging-specific curricula for specific subject matter areas (e.g., social studies, health). Gerontology educators have collaborated with K-12 teachers and curriculum specialists to develop curriculum materials and to gain the approval of accrediting agencies and state education departments for the new curricula. Ideally, another effort should infuse aging education into the teacher education and educational administration curriculum by developing a teaching minor in gerontology, accepting some gerontology courses as electives in the degree program, or offering in-service workshops for teachers and administrators. Toward such efforts, gerontological specialists can serve as curriculum developers and consultants or as providers of the in-service training programs.

Music Therapy, Art Therapy, and Writing Program Recent research shows the value of music therapy, art therapy, and writing programs for community-dwelling and institutionalized older adults, especially for those with depression and dementia. These findings open the door for links between gerontology and the humanities in academic education programs and the development of additional career opportunities for gerontological specialists as therapists, program designers, and program leaders.

Applied and Clinical Sociology Some sociology departments are in the process of developing applied or clinical sociology programs at the bachelor's and master's degree level; a few of these programs include tracks in aging. Applied sociology involves the application of sociology knowledge in understanding and solving social problems. Clinical sociology extends knowledge application to the level of intervention and guidance of change processes. Applied and clinical sociologists have expertise in using the techniques of impact assessment, evaluation, mediation, and conflict resolution, counseling, and facilitation. Gerontological specialists in applied or clinical sociology should be able to find career paths in media outlets and mass communication as researchers, news and policy analysts, and pollsters and poll analysts. With mediation and conflict resolution skills, they might work as ombudspersons in long-term care and residential centers for elders, in family mediation, and in community development.

Substance Abuse and Chemical Dependency While some aging persons bring with them into old age the substance abuse problems from across a lifetime, others develop substance abuse and chemical dependency problems in later life. This opens up new career opportunities for gerontological specialization in professional fields such as law enforcement, pharmacy, nursing, medicine, and counseling.

Family Gerontology Emerging from within the field of family studies, family gerontology recognizes the impact of changes in family structure, processes, and relationships on older family members. Current hot areas of professional practice with elders and their families relate to caregiving for elderly family members, grandparents raising grandchildren, and grandparent visitation rights. This opens new career path opportunities for gerontological specialists as family life educators and program administrators, family and elder law attorneys, family mediators, family therapists, and family gerontology policy specialists.

Entrepreneurial Gerontology Gerontological specialists often look for niche opportunities to meet the needs and interests of older adults in unique and creative new ways. Entrepreneurial gerontology allows professionals to develop new tools, products, programs, and delivery systems through their positions as consultants, product developers, project or program managers, and small business owners. For example, one gerontological specialist in interior design now assists older persons with housing transitions, while another consults with small town chambers of commerce and business owners interested in helping their clientele age in place. A former gerontology program director is a traveling professor who teaches condensed-schedule and distance learning niche courses (e.g., sexuality and aging, women and aging) on campuses where resident expertise is not available. A burned-out adult protective services social worker now presents elder abuse prevention seminars and workshops. A new graduate with a bachelor's degree in clothing and textiles and a minor

in gerontology created a position with a long-term care facility to design and make adaptive clothing for elderly residents and dementia patients. Yet another gerontological specialist trains managers and staff members of chain restaurants in regard to employment of older adults and providing age-appropriate services for older clients. These real and hypothetical situations only hint at the possibilities for gerontological specialists in entrepreneurial gerontology.

Conclusion

The field of aging is a tremendously diverse field that offers a wide array of professional career paths. As noted, some of these paths are through traditional career positions within traditional professions and academic disciplines. New career options also are emerging in both traditional fields and emerging subfields of gerontology or related professions. Yet other career opportunities are available in disciplines and professional fields not addressed here (e.g., anthropology, history, spirituality and religion, marketing, advertising, public policy). Also, persons interested in working with, for, and/or on behalf of elders can now develop their own niche practice as entrepreneurial gerontologists and gerontological specialists. Increases in life expectancy and a growing population of elders with diverse needs and interests should encourage the development of even more and different types of professional practice in the field of aging.

With many existing professional positions in the field of aging and the potential for development of yet more types of career paths related to aging, it is vital that adequate gerontology education opportunities exist to prepare new professionals in a wider array of academic disciplines and professional fields. Toward this end, it is necessary to more clearly define what a gerontologist is and what a gerontological specialist is. Development of a career ladder for the field of aging is recommended. Along with degree- and certificate-based career paths, this career ladder needs to include paraprofessional positions that require gerontological content in the training programs. To be effective in such a diverse career field, the ladder must combine the best features from both continuum and hierarchical models so that it allows for increasing complexity and responsibility, as well as for parallel but differentiated career paths. Gerontology program administrators and faculty members must work harder to introduce students to gerontological career options earlier in the students' college experience. Faculty members from more departments and programs across campuses need assistance in identifying gerontology-specific and -related opportunities that are possible in their disciplines and professions. It is vital that university administrators (e.g., deans, provosts, presidents, chancellors) gain a broader understanding of the importance of gerontology education for all students and support gerontology-specific career path education that exists or could exist on their campuses. Finally, it is necessary to educate the general public about the value of adequately educated professionals in the field of aging and the benefits gained through working with gerontological specialists in many, if not all, aspects of their lives.

See also: History of Gerontology; Organizations On Aging.

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Caregiving and Caring

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Glossary

Care Receiver – A person who requires day-to-day assistance due to illness, accident, or disability.

Community-Dwelling Adult – An adult who lives in a private home rather than in an institutional setting.

Formal Caregiver – An individual associated with a service organization or independent contractor who is paid to provide or manage care for persons with chronic illnesses or disabilities. Volunteers associated with a service organization are also considered formal caregivers.

Informal Caregiver – A family member or friend, typically unpaid, who provides or manages care for a person with a chronic illness or disability.

Long-Term Care – Assistance provided over an extended period of time due to chronic illness or disability either at home or in an institution.

Introduction

Caregiving is the act of providing assistance or care to a family member, friend, or client with a chronic illness or disability so that she or he can maintain an optimal level of independence with dignity. This assistance can be instrumental or hands-on, affective, financial, or otherwise of value or necessity to the care receiver. Caregiving varies in its intensity and duration, ranging from 1 hour per day, or one weekend per year, to 24 hours a day for years at a time. Caregiving can occur within a community or home setting, an institutional or assisted living setting, or from a distance. Although providing care can be stressful to both caregivers and care recipients, the effects on caregivers can be long term, lasting for many years after care responsibilities have ended.

Background on Caregiving

Research on informal and formal caregivers has grown dramatically in both quality and quantity over the past decades. With increasing sophistication in both theory and methodology, caregiving research at the beginning of the twenty-first century is characterized by its continued advances in theory, methodology, interventions, and application for policy development. To appreciate the growing significance of caregiving research, it is important to understand caregiving's prevalence and impact as well as current conceptual frameworks that guide and evolve from empirical findings.

Prevalence of Caregiving

The growing percentage of adults age 65 and older in the United States, and particularly those over the age of 85, has a dramatic effect on the prevalence of caregiving. In 1980, 11.2% of the population was 65 years of age or older, and in 2000 this percentage had increased to 12.4%. Moreover, it is projected that by the year 2050, over 20% of the US population will be at least 65 years old.

It is estimated that more than 7 million of the 33.3 million adults in the United States age 65 and older require assistance with personal care or daily activities such as bathing, dressing, and housekeeping. By and large, families and friends provide the majority of assistance with hands-on care as well as emotional and financial support. Specifically, 71% of all long-term care is provided to older adults in the community by an estimated 5.8 to 7 million family members and friends. These estimates are based on the 7 to 8 million community-dwelling elderly with at least one functional disability or with Alzheimer's disease or other type of degenerative dementia. When younger disabled persons (i.e., those age 20 and older) are included, the estimated number of informal caregivers rises to 52 million. An additional 1.69 million informal caregivers continue to provide some level of assistance to their relatives when they are institutionalized.

Types of Care

Empirical research documents the wide variety of help required in relation to the characteristics of both the caregiver and care receiver. One critical factor is the type of functional impairment and the nature of the debilitating disease. For those over age 65, impairments include sensory (14.2% or 4.7 million), physical (28.6% or 9.5 million), mental (10.8% or 3.6 million), self-care (9.5% or 3.2 million), or difficulty going out of the home (20.4% or 6.8 million).

Another factor is presence of cognitive impairment, because these adults have different care needs compared to physically impaired adults who are

cognitively intact. For example, caregivers of adults with physical impairments (e.g., stroke, multiple sclerosis) report providing substantial assistance with self-care activities such as bathing, dressing, and walking. In addition to assisting with self-care activities, caregivers of adults with cognitive impairments (e.g., Alzheimer's disease, degenerative dementia) report spending a great deal of time and energy dealing with their relative's problem behaviors, such as agitation, memory loss, and wandering.

Additional factors that affect care provision include social network characteristics, household income, and access to community services. It is often assumed that caregivers use formal services only after they have exhausted all sources of informal assistance. While this is true for many families, access to services is also linked to factors related to social network characteristics such as its size, the proximity of network members, and their knowledge of community resources. Income level also is associated with use of formal services because most community-based long-term care is paid out-of-pocket. Thus, income and network characteristics are interrelated and instrumental to the accessibility of services.

Providers of Care

Informal Caregivers

The care received by millions of older adults comes from a variety of sources. Although informal care is the most preferred and frequently used source of assistance for older adults, formal care services also supply a great deal of support, especially for the millions of older adults who live alone or have no family or friends available to assist. Older adults who have a choice, however, prefer that family and friends help them once assistance becomes necessary.

Primary and Secondary Caregivers When assistance becomes necessary, families often go through a period of reorganization as they restructure their lives. Frequently, one individual, whether by choice, availability, or convenience, becomes the primary caregiver. The job of the primary caregiver, although rarely specified, is to be the direct provider and/or manager of the elder's care. The stressful and long-term nature of providing care causes many primary caregivers to seek assistance from other family members, friends, or service providers. However, it is understood, though not necessarily made explicit, that the primary caregiver is the main person in charge of the relative's care.

A naturally occurring hierarchy seems to exist within families that often leads to a designated primary caregiver. When care recipients are married, spouses will most likely become the primary caregiver. Adult daughters are also likely candidates. According to Spector *et al.*, approximately 13.4% of family caregivers are wives, 10.0% are husbands, 26.6% are adult daughters, 14.7% are sons, and another 17.5% and 8.6% are 'other' female or male relatives, respectively. In addition, the quality of the caregiver's relationship with the care receiver is associated with who will provide care. Family members who have contentious or antagonistic relationships with the care receiver are less likely to provide care than those relatives who are more compatible. Unfortunately, when the caregiver and care receiver are not compatible, it is common for both to experience heightened distress.

The health of family members, proximity to the care receiver, and demands of their daily lives are additional factors that influence whether or not a family member will become the primary caregiver. These factors also influence the level of involvement family members have in the provision of care. If a family member is in poor health or is at risk for worsening health, he or she is less likely to become a primary caregiver. About one-third of primary caregivers assume the role because they live closer to the care recipient, although an increasing number of family members are assuming care responsibilities from long distances. Relatives with multiple or competing family demands (e.g., employment, child care needs) are also less likely to be caregivers. However, even under demanding and stressful conditions, family members are still more likely than service providers to provide care.

In contrast to the primary caregiver, secondary caregivers typically provide unpaid supplemental or intermittent assistance. Most older adults have more than one informal caregiver, although informal caregiving networks tend to be relatively small, averaging two in number. Secondary caregivers typically supplement the help provided by primary caregivers, particularly in the areas of household tasks, personal care, and socialization. In contrast, assistance with money management and medical care appears to remain the responsibility of one caregiver, generally the one who has more expertise in the area. Secondary caregivers also supply important assistance to the primary caregiver as well as the care receiver. They are a prominent source of companionship and emotional support for the primary caregiver as well as a source of respite or relief from caregiving responsibilities. In total, informal caregiving networks supply an average of 7 hours of help daily to community-residing impaired older persons.

Home-Based versus Institutional Care The responsibilities of caregivers were once thought to end once a care receiver entered an institutional setting such as a nursing home. Research indicates that caregivers continue to remain active in the lives of their impaired family members once institutionalization is necessary. Family caregivers visit often and may travel great distances to spend time with their relatives. Caregivers of nursing home residents often perform many of the tasks they did while caring at home, including assistance with eating and walking. In fact, a large majority of caregivers remain active in the lives of their relatives for many years after they enter the institution.

The continued involvement of family caregivers following placement, however, may result in additional or new sources of distress. Once their relative is institutionalized, caregivers must restructure their lives and adjust to their new role. Research indicates that the stresses of caregiving are not alleviated by placement. Although these caregivers are relieved of the day-to-day demands of caregiving, many continue to feel distress, and some exhibit symptoms well above their pre-placement levels of distress. Thus, it appears that placement alters rather than eliminates stress.

Consequences of Caregiving There is substantial empirical evidence indicating that the stress of providing in-home care over the long term affects a caregiver's mental and physical health. Caregivers are more depressed than age-matched controls, exhibit deficits in physical health and depressed immunologic functioning, use prescription drugs for depression, anxiety, and insomnia two to three times as often as the rest of the population, and have higher rates of comorbid health conditions and mortality.

Caregivers also report financial strain as a result of providing in-home or institutional care over the long term. In some areas of the United States, for example, the cost of caring for an adult with Alzheimer's disease has been estimated to be $50 000 per year. Compared to their age peers in the general population, caregivers are more likely to report adjusted family incomes below the poverty line. Adding to this financial strain is the fact that care-related responsibilities often lead to changes in work status. Caregivers often lose time from work, chose to retire early, or give up work entirely while they are helping their impaired relative.

Another potential consequence of caregiving is its negative effects on the caregiver's relationships with family members and friends and decreased time for leisure and social activities. Families that have difficulty problem solving, coordinating their efforts, and communicating often have difficulty planning and managing the long-term care of their relative, as do those with a history of dysfunctional relationships. This often results in family conflict regarding caregiving arrangements and can even lead to the estrangement of one or more family members. On the other hand, family caregivers often complain that they have no personal or leisure time. Hence, their participation in social and recreational activities declines, as does their ability to travel and take vacations, which can lead to social isolation and loneliness. Some caregivers even complain of not enough time to attend to important personal needs such as medical appointments and exercising.

Characteristics of the care receiver's illness are related to compromised health for caregivers. For example, the severity of the care receiver's illness has been found to be the most important predictor of caregiver stress. This finding is similar for caregivers of persons with stroke, dementia, cancer, and other debilitating illnesses. When the impaired persons' behaviors become unpredictable and ambiguous, caregiver distress is often exacerbated. Thus, behaviors such as acting out, wandering, and agitation are associated with increased caregiver distress. Last, cognitive impairment during the early stages of a disease appears to be more stressful for caregivers than cognitive impairment in the later stages.

Despite the extensive evidence about the adverse effects of caregiving, some evidence suggests that caregivers can experience positive effects from the experience. Although far less research has been directed to the benefits of caregiving, existing evidence indicates that caregivers often define the experience as satisfying, one that gives meaning to their lives and provides a sense of personal mastery or self-efficacy. It is important to gain more knowledge about caregiving's benefits in order to have a more balanced perspective on the caregiving experience and to enable clinicians and service providers to use a strength-based approach to service plans that capitalize on caregivers' capabilities.

Formal Care

Compared to persons younger than 65 years of age, older persons disproportionately utilize more acute and long-term health-care services, whether home- and community-based or institutional (hospital and nursing home). Consequently, they and their informal caregivers are more widely affected by legislation that significantly changed reimbursement for health care and led to corresponding changes in health-care provision. In 1983, the implementation of the Medicare Hospital Prospective Payment

System dramatically altered admission and discharge patterns, effectively transferring 21 million hospital days to home and community. The 'sicker and quicker' discharge of older persons from the hospital placed a heavier burden on informal caregivers and spurred the growth of hospital-based and proprietary home-care agencies.

Another important piece of legislation designed to improve the quality of care in nursing homes was the Omnibus Budget Reconciliation Act (OBRA), passed in 1987. It led to an increase in training requirements for nursing home staff and changes in resident care planning and monitoring. OBRA also addressed the pressing issue of the frequent impoverishment of community-dwelling spouses of nursing home residents. It mandated policies allowing these spouses to retain the equity in their home and one-half of their other assets so they could continue living independently. However, it is not clear that these changes actually resulted in improved care, more positive attitudes toward nursing homes, and decreased spousal impoverishment.

The National Family Caregiver Support Program (NFCSP), funded through the Older Americans Act reauthorization in 2000, is the most comprehensive federal legislation that supports caregivers of older relatives, grandparents, and other relatives who care for children 18 years of age and younger, and older adults caring for persons with developmental disabilities. As part of the NFCSP, states are expected to work with area agencies on aging (AAAs) to develop multifaceted systems of caregiver support in five areas: (1) information about available caregiver services, (2) assistance in gaining access to services, (3) counseling and the organization of support groups and caregiver training, (4) respite care, and (5) other services that complement the care provided by caregivers. As yet, it is unclear how these dramatic changes in reimbursement and the organization of health-care systems will affect older persons' patterns of formal service use and their outcomes, alter the role of family caregivers, and affect attitudes toward and patterns of nursing home use.

Prevalence of Community-Based and Institutional Service Use Findings from the 1987 National Medical Expenditure Survey indicate only 36% of the 5.6 million Americans age 65 and over with functional disabilities use community-based services (e.g., home health care, homemaker, day programs, telephone monitoring, special transportation, senior centers offering congregate meals). The majority of this care (75%) is paid for by the individual, while the public sector covers the cost for the remaining one-fourth. More recent information on home-care expenditures following passage of the Balanced Budget Act in 1997 shows the elderly population had the greatest decline between 1996 and 1999 in use of paid home-care services, primarily those reimbursed under Medicare. With negative changes in the US economy since 2001 and shortfalls in state budgets, federal and state dollars available to cover the costs of home- and community-based services are shrinking.

About 20% of disabled older persons rely on formal services, while 16% combine informal with formal care, 35% exclusively use informal care, and 29% have no assistance. Home care is the most widely reported service used, although studies involving the older population in general suggest that services offered by senior centers are more commonly utilized. The most frequently used type of help by disabled elderly is housekeeping and meals; in fact, housekeeping is also the most widely used assistance by elderly without chronic disabilities. Among disabled older persons receiving community-based services, over two-thirds use entirely home-based services. This sizable group of home-based services users is composed largely of the most severely impaired older adults. Another one-fourth of older adults rely exclusively on out-of-home services at senior centers, day programs, and congregate meal sites. A small minority (about 10%) combine in-home with out-of-home services.

Long-term residential care services are used by only 5% of the elderly at any given time. However, 25 to 35% of older Americans can expect to spend some time during their later life in a nursing home. In addition to the problems related to combining private living space with ongoing medical care and generally unfavorable attitudes toward nursing homes, the high cost of nursing home care dissuades many elderly and their families from its use or causes them to use it only as the last option. An alternative to nursing home care is assisted living, which maximizes the older person's lifestyle choices in a less restrictive housing environment that also supplies supportive services (e.g., housekeeping, transportation, meals, and sometimes supervision of medications and personal care) (*see* Long-Term Care).

Predictors of Service Use by Older Persons and Their Caregivers The stressful nature of caregiving has led many researchers to examine the impact of service use on caregiver well-being. Social support models have been adapted and applied to explain the elderly's use of both informal and formal assistance. This approach is based on the recognition that the exclusion of formal service use from models of social support weakens the full effects that

assistance from others has on the individual's adjustment to negative life events. Moreover, these models incorporate the fact that informal and formal helpers often perform similar functions for chronically ill older persons, including emotional support and instrumental help with personal care and household tasks.

Many of the same predictors explain the elderly's use of community-based and nursing home care. These predictors include advanced age, gender (female), cultural background (Euro-American), marital status (unmarried), living arrangement (alone), and level of functional disability. Additionally, the absence of a willing, able, and proximate informal caregiver is a major factor in nursing home placement. This is particularly salient when the older individual has a neurological condition such as a stroke. Generally, family members control the timing of nursing home entry and physicians exert a major influence on the decision, particularly when discharge planning from the hospital is involved.

Research has examined predictors of mixed helping networks for elderly living at home. Formal and informal help are more commonly used when the elderly person is of more advanced age, is living alone, and is more functionally impaired; the informal caregiver(s) is a more distant or unrelated kin member; and more financial resources are available to purchase services. Interestingly, including race as a predictor of mixed helping networks has had little explanatory power once other important factors, namely, functional status and health change, were controlled. Consistent with findings from most studies, women and those living alone are more likely to have mixed networks, Whites disproportionately tend to use nursing home care, and married elderly tend not to use formal helpers. Although African American elderly are less often married, their typically larger households and greater variety of informal helpers are thought to counterbalance the absence of a spouse caregiver.

Since the mid-1980s, services targeted to informal caregivers have been developed and have become more widely available based on the demonstrated stressful effects of long-term caregiving. These services include respite care, peer- and professionally led support groups, educational programs in care-related skills, training in problem-solving skills and behavioral techniques for patient management, and counseling and psychotherapy. Evaluations of these interventions have yielded mixed results, and a number have been compromised by sampling and other methodological limitations. Research studies are focused increasingly on determining the most effective intervention for specific types of caregivers, the most effective timing of these interventions, and the most appropriate duration of use.

One difficulty commonly encountered in evaluations of caregiver interventions is enrolling sufficient numbers of caregivers in study samples, even when the service is provided free of charge. Various explanations offered for the apparent underutilization of care-related services include unfamiliarity with the service, lack of perceived need, reliance on informal helpers for care-related assistance, absence of culturally relevant services, and barriers to the service system and the delivery of services. To date, relatively little empirical attention has been given to the prevalence, sources, and predictors of care-related service use. In general, however, the predictors of caregiver service use are kinship tie (adult child), living with the care receiver, being employed, more perceived care-related stress, and more informal and formal assistance provided to the care receiver.

Heterogeneity among Caregivers

It is well documented that caregivers experience their role differently depending upon their gender, kinship tie, age, and cultural or ethnic identity. Advanced research designs and methodological techniques have led to a better understanding of the interrelationships among the sociodemographic characteristics of caregivers and their impact on care-related outcomes.

Gender and Kinship Ties Studies of caregiving families indicate that women are more likely than men to (1) take on the role of caregiver, (2) spend more time providing care whether they are employed or not, and (3) provide personal care assistance. Male caregivers tend to take on more instrumental tasks such as decision making and financial management. Among men, husbands are most likely to be caregivers; sons and sons-in-law are much less likely to take on the role. In fact, it is more common for an older woman to be cared for by her daughter-in-law than by her son. Women report greater distress than men, regardless of the care receiver's diagnosis and level of impairment and the caregiver's employment status. Studies that compare adult daughter and wife caregivers suggest mixed results: some studies find daughters to be more distressed, while other studies report the reverse or find no differences by kinship tie.

One explanation for these gender and kinship differences draws upon studies of health and well-being in the general population indicating that women commonly score higher than men on indicators of stress, suggesting women may be more comfortable than men expressing feelings of stress. It has also been suggested that the nurturant role developed by

men in later life may be rewarding or act as a form of repayment for the care they received in the past, which in turn helps to counteract the otherwise negative effects of caregiving.

Age The effects of caregiver age are nearly impossible to disentangle from the effects of other caregiver and care receiver characteristics. For example, age and kinship tie are confounded for spouse caregivers who are significantly older than other groups of caregivers. In addition, there is conflicting evidence about the relationship between caregiver age and distress; some studies find older caregivers to be the most distressed, while other studies find younger caregivers to be the most stressed. However, among employed caregivers, especially those with both child- and adult-care responsibilities, younger caregivers are more likely to experience greater distress as well as absenteeism, interruptions at work, and difficulty in combining work and family.

A related issue concerns older generations caring for younger generations. It is common for elderly parents to care for their disabled adult children and grandchildren. Within the African American community, increasing numbers of mid-life and older women have primary responsibility for their grandchildren and great-grandchildren. Typically, a family crisis precipitates a grandparent taking on the caregiving role, such as the incarceration or death of the grandchildren's parent. The conditions under which grandparents generally, and grandmothers in particular, become caregivers often reflect the broader social context within which these older caregivers live. Furthermore, the circumstances resulting in the parent's inability to care for the child often compound the problems that grandparents encounter in caregiving. Some of these problems include little or no child support, low income, inferior family leave policies, and inadequate social support, as well as the caregivers' own physical health problems. Differences in this phenomenon are evident by cultural group: 12% of African American children live with grandparents, compared to 5.8% of Hispanic children and 3.6% of White children.

Ethnic and Cultural Differences Until the 1990s, little was known about the how the caregiving experience varies in relation to cultural and ethnic identities. Advances in cross-cultural research have demonstrated the diversity among caregivers throughout the world, including differences between developing and developed countries, and urban and rural settings.

Within the United States, research indicates both similarities and differences among caregivers depending upon their ethnicity. Some work suggests that for family members caring for relatives with a variety of disabilities, there is no clear relationship between the caregivers' ethnicity and the amount of stress they experience. Yet regardless of the ethnic background or identity of a caregiver, it is clear that across all ethnic groups family care is the most preferred and relied upon source of assistance. Extensive and supportive kin networks have been documented in Americans of all ethnic backgrounds, including Mexican Americans, African Americans, Asian Americans, and Euro-Americans (e.g., Greek, Italian, Polish, Irish).

Currently, the predominant theme in caregiving is to focus on the differences between Euro- and non-Euro-American caregivers with little attention paid to the great heterogeneity within different ethnic groups. For example, Euro-American caregivers are frequently compared to Asian, Hispanic, or African American caregivers. Growing evidence indicates that differences between these groups are less pronounced than differences within the groups. In addition, it has been suggested that group differences may be more related to the length of time since immigration than to specific ethnic background. As a result, there has been a call to shift efforts away from intergroup study and instead to focus attention on intragroup differences.

Theories of Caregiving

The following sections present a brief overview of theories related to family caregiving. These theories, although not exhaustive, represent the conceptual developments that have influenced caregiving research over the past decades. The overview and integration are presented to foster expansion of the theoretical foundation of caregiving research.

Social Functioning

Social Competence and Breakdown Theory The social competence and breakdown theory, presented by Kuypers and Bengtson, posits that the negative consequences of aging (e.g., illness, loss) can lead to a breakdown in the social competence of the elderly. At risk are elderly individuals with a self-concept that has been diminished because of role losses (e.g., widowhood) and negative stereotypes about the elderly (e.g., ageism). When they experience a health or other crisis, it can result in health professionals, family, or others in the social environment labeling the person as dependent. If the older person accepts this definition, it leads to further vulnerability and the negative cycle escalates, with further adverse

consequences to social and psychological competence. In adapting this model to problems facing the aging family, Bengtson and Kuypers suggest that the sudden dependency of an elderly family member can lead to caregiving problems that test the competence of the family as well as the individual. A thorough understanding of the nature of individual–familial–environmental interactions affecting competence can facilitate the identification of interventions that may improve family functioning and reduce the sense of helplessness felt by many caregivers.

Models Linking Formal and Informal Support Several models have been proposed for conceptualizing the relationship between informal (unpaid) and formal (paid) helpers. First, Cantor's hierarchical compensatory model proposes that the elderly's preferences for informal caregivers reflect a normative pattern in the intimacy or closeness of social relationships. Thus, the caregiving role is taken on by the closest family member, with spouses as first choice, followed by children, other kin, friends or neighbors, and formal helpers. In cases of more severe functional impairment, assistance needs, and limited availability of informal helpers, more overlap between informal and formal helpers is likely to occur.

A second conceptualization is Litwak's task-specific model. In this model, the appropriate source of help is tied to the type of task. Informal helpers are best suited to non-technical tasks and those that cannot be scheduled (toileting, transferring); formal helpers can best manage specialized tasks that can be scheduled. As a result, the allocation of tasks between informal and formal tasks reflects a clear division of labor with 'dual specialization' or task segregation. This arrangement minimizes conflict and other negative outcomes occurring between the two types of helpers.

An alternative perspective gave rise to the supplementation model of Edelman and Hughes, who suggest that task sharing mainly occurs between the elderly's informal and formal helpers. Because most assistance needed by disabled elderly is routine help with personal care and daily activities, supplementation by formal helpers alleviates the time-consuming and potentially exhausting demands on informal caregivers.

In contrast, it has been hypothesized that, given the option, formal care would be used by families to substitute for informal care. Greene's substitution model gives pause to planners and policy makers who advocate expanded reimbursement for community-based services because it is widely recognized that the public sector cannot assume the full cost of long-term care for disabled persons. However, there is little empirical evidence that families would abrogate their role as the primary source of assistance to older impaired relatives if service availability is expanded.

Gender Theory The application of gender theories of caregiving has increased since the 1980s. This body of work has been greatly informed by feminist scholarship and has its roots in the gender socialization framework and social role perspective. Gender socialization proposes that gender roles are internalized as stable personality traits and result from gender differences in socialization during childhood. In contrast, a social role perspective explains gender differences in behaviors as the result of a person's current and continuous construction of social realities and the related role demands of these realities. Using a gender socialization framework to understand gender differences in caregiving and caring, one would expect early role socialization and personality factors to be linked to greater involvement of women in caregiving tasks. In contrast, a social role perspective would posit that women are more involved than men in caring activities because women have fewer alternative roles as a result of their limited access to diverse social resources. However, research has moved away from these two views of gender, focusing instead on issues related to inequity and identity. This redirection is due in part to the fact that women, by default, perform more care tasks than men and, in turn, express being more distressed. Moreover, distinct stressors affect women caregivers who often provide care both on the job and at home, which increases their vulnerability to stress. In general, feminist scholars do not promote the view of caring as a universal element of women's identity, or as a human quality, separate from the cultural and structural circumstances that create it. To feminist scholars, caring is a process that maintains and repairs our world and, in turn, one that should be highly valued within our world.

Family and Individual Functioning

A number of researchers have introduced theoretical perspectives that draw upon models of family systems and individual functioning. First, the study of caregiving systems and dyads has its roots in family systems theory and research. For example, Thompson and Walker have studied patterns of attachment, aid, and communication among grandmothers, mothers, and granddaughters, resulting in a rethinking of the unit of analysis in caregiving research (i.e., generations). Kahana and colleagues also use a dyadic conceptualization based on the view that

illness is not singularly experienced and causes diverse patient-family outcomes.

Second, the circumplex model of family functioning, proposed by Olson, Spenkle, and Russel, describes family cohesion and adaptability as determinants of the family's ability to accomplish developmental tasks and cope with stressors (such as long-term illness). Cohesion is the degree of bonding within a family group, whereas adaptability represents the degree of flexibility demonstrated by the family. For optimal family functioning, families should be balanced on both factors. For a family dealing with long-term disability, the circumplex model suggests that poor adaptation is a result of an imbalance of cohesion and adaptability. Although the model does not suggest specific therapeutic techniques for correcting an imbalance, the authors suggest that it is therapeutically useful to share the assessment with the family.

Third, the double ABCX model of illness adaptation of McCubbin and Patterson proposes that an event such as an illness (A), invokes a family's resources (B) and, depending upon how the family interprets the event (C), a crisis may be produced (X). Thus, a family's ability to invoke resources (e.g., community, family, and personal) and coping responses is related to how family process shapes the course and ease of a family's adjustment and adaptation over time. The emphasis on family resources and coping responses is critical to further adapting the ABCX model to the potential crisis of family caregiving. Families with adequate resources and coping responses may not reach a crisis point. In the future, it may prove useful for researchers to use the ABCX model in order to focus their efforts on the study of well-adapted family caregivers.

Last, Pearlin and his colleagues have developed the stress process model of family caregiving with its roots in sociological and psychological theories of stress and coping. They conceptualize the caregiving experience as a 'career,' thus allowing a framework for identifying continuities and discontinuities in the lives of family caregivers. Transitions occur in this career as individuals provide long-term care for chronically ill or demented family members. The stages include (1) role acquisition, when the individual takes on care responsibilities; (2) role enactment, consisting of the in-home care period; (3) the transition to institutional care, when in-home care is replaced by full-time institutional care; (4) death of the care recipient, including the period of bereavement and grief; and (5) social reintegration, when the caregiver works toward becoming reintegrated into the social environment.

This model conceptualizes the experience of caregiving as a chronic stressor that proliferates and reconfigures over time. The model focuses on background characteristics, primary and secondary stressors, and mediators of stress as well as their interaction to produce various outcomes. Background characteristics (e.g., age, gender, ethnicity) exert their influence throughout the caregiving process, whereas primary stressors are the objective and subjective indicators of care-related needs. Secondary stressors (i.e., role strains such as work and family conflict, and intrapsychic strains such as loss of self and mastery) are the products of primary stressors, not because they are less potent than primary stressors but because they grow out of the care process. Over time, as the care receiver's condition worsens, primary and secondary stressors proliferate, which leads to negative caregiver outcomes such as depression and compromised health. Mediating conditions such as social support or services act to limit this proliferation by lessening the negative effects of the stress.

Taken together, primary and secondary stressors and mediating conditions reveal the dynamic and complex nature of caregiving. Clear specification of the interrelatedness of these domains allows the precise delineation of their influences on caregiving outcomes. Moreover, this model provides a framework for the development and empirical testing of caregiver interventions designed to contain the proliferation of caregiving stressors.

Theory Building: Integration and Expansion of Current Theories

Drawing upon overlapping components and empirical findings from the theories described earlier, we propose a theoretical model that directs attention to specific points for intervention in the caregiving process. This model draws heavily upon the stress process model of family caregiving and highlights the importance of multidimensional models, longitudinal designs, and the bridge between research and practice.

From previous research we know that specific components of the stress process model are related and different types of social support work to alleviate many of the negative effects between stressors. For example, **Figure 1** demonstrates the empirically known relationships that exist between stressors and how social support acts to buffer these negative interactions (see dashed arrows in **Figure 1**). Both formal and informal instrumental support as well as emotional support acts to moderate or buffer the deleterious effects of stress at specific points within this model. The dashed arrows of **Figure 1** show that formal support lessens the negative effects of a care receiver's functional loss on a caregiver's feeling of role overload

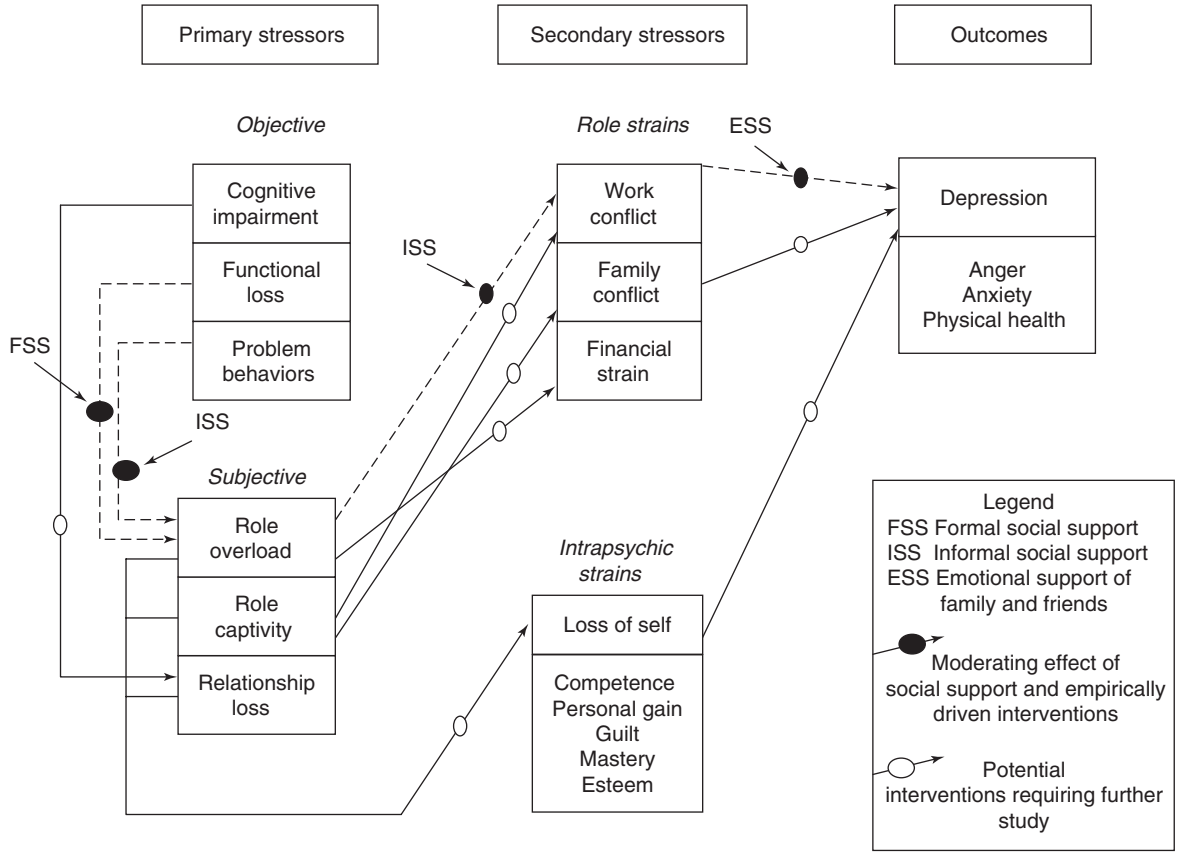

Figure 1 Potential interventions based on empirical findings. From Whitlatch and Noelker (1996) *Encyclopedia of Gerontology*.

(burnout). On the other hand, informal support lessens the negative effects of a care receiver's problematic behavior on a caregiver's feeling of role overload.

Figure 1 also reflects the empirical relationships showing that role overload is associated with increased work conflict that, in turn, relates to increased depression. Here we see the differential buffering effects of support on work conflict and depression. While informal support lessens the negative effect of caregiver overload on caregiver work conflict, emotional support helps to moderate the negative effects of caregiver work conflict on depression. Based on empirical findings, we see that there are a number of points in the stress process where social support can alleviate different types of caregiver distress.

Additional research suggests efficacious points at which social support may act to intervene in order to moderate the negative effects of stressors. The unbroken lines seen in **Figure 1** reflect the results of research suggesting that specific relationships exist among a variety of stressors. For example, research has found that care receiver cognitive impairment leads to a sense of relationship loss for the caregiver. Currently, however, we know little about how social support acts to buffer these and other potentially negative effects.

We also know that subjective primary stressors (i.e., role overload, role captivity, and relationship loss) are related to a caregiver's loss of self. In turn, loss of self is associated with increased levels of caregiver depression. Given that social support ameliorates the deleterious effects of comparable components of the stress model, it is likely that social support could similarly lessen the negative effect of subjective primary stressors on the caregiver's loss of self, and, in turn, lessen the negative effect of loss of self on depression.

These examples illustrate the potential utility of interventions based on related empirical findings. Yet there are numerous pathways within the stress process model that are yet unexplored. For example, we know little about the precursors to caregiving outcomes such as anger, anxiety, and declining physical health. Research that documents the interrelationships among these factors over time, as well as the impact of social support in moderating the effects of these relationships, will help to inform intervention techniques.

See also: Andropause; Dementia; Demography; Ethnicity and Minorities; Health Care and Services; Hospice.

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Cell Death

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Glossary

Apoptosis – Death of a cell through a characteristic pattern including most or all of the following: cell shrinkage, margination of chromatin, fragmentation, destruction of DNA by digestion at nucleosome bridges, and non-inflammatory phagocytosis.

Bcl-2 – An oncogene, named after the cancer in which it was discovered, B-cell lymphoma-2. A B cell is a type of immunocompetent cell. *Bcl*-2 acts by preventing cell death rather than by stimulating cell division.

Fas, Fas Ligand – Fas is a protein expressed by several cells, and fas ligand (FasL) is a cell surface protein similar to tumor necrosis factor. When T cells are activated, they express FasL, inducing apoptosis. Failure of this interaction has been associated with autoimmune diseases and excess proliferation of T cells.

Immunocompetent Cells – Any of several related cells of the immune system, which variously retain memory of foreign proteins that have been encountered, communicate this information to other cells, synthesize antibodies against these proteins, or actively destroy infected, invading, or damaged cells.

Necrosis – Death of a cell by loss of control of energy resources and ion balance, resulting in cell swelling and rupture, producing an inflammatory response.

Nucleosome – Organized grouping of basic proteins (histones) around which DNA wraps. There is approximately one nucleosome for every 180 base pairs of DNA.

Oncogene – Gene involved in cell growth and division, often associated with mechanisms regulating mitosis. The term oncogene (cancer gene) refers to the fact that these normal cellular genes have been captured by viruses, leading to their uncontrolled expression and consequent loss of regulation of growth in infected cells.

Phagocytosis – Consumption of one cell by another. The consuming cell is termed a phagocyte. Some cells (macrophages) are designed to destroy other cells, and are considered professional phagocytes. Others may consume a dead neighboring cell and are considered to be amateur phagocytes.

Programmed Cell Death – Death of a cell by a mechanism involving an identified sequence of steps to its death, often in non-toxic circumstances, and frequently requiring activation of specific genes. In appearance, the collapse is usually but not always apoptotic.

Introduction

The term cell death has three meanings. It refers to a limited potential for division of normal cells in culture, disappearance of cells during the normal life

span of an individual, and the highly controlled suicide of cells. An age-related decline in function of the immune system may reflect the first meaning, the limited life span of cultured cells. The second is poorly defined but presumably results from cell suicide, otherwise described as programmed cell death or apoptosis, which is often controlled by specific genes that protect or destroy cells. This controlled cell death is important in the development of the nervous system and in the differentiation and death of cells in the immune system. Failure of programmed cell death or apoptosis can lead to cancer and autoimmune disease, and excessive cell death can result in immune failure, neurodegeneration, or loss of cells in an infarct. Future therapies are likely to attempt to regulate programmed cell death and apoptosis.

Definition of the Term Cell Death

Cell death, particularly in the context of aging, has at least three meanings for different audiences. First and most familiar to non-research audiences, is loss of cells as an individual ages through pathology or perhaps reasons that cannot be attributed to any specific abnormality other than the passage of time. For the gerontologist, this loss is most critical in the immune system, because it leads to substantial increase in susceptibility to infection; in the central nervous system (CNS), because lost neurons are currently irreplaceable, and in the skeletal muscle, because these cells are likewise irreplaceable. In a less absolute sense, cirrhotic loss of cells in the liver is not followed by regeneration, and this loss also therefore becomes life threatening.

The second major sense of the term cell death is reference to the failure of most normal vertebrate cells to reproduce indefinitely in culture, also described as limited life span of cells in culture. Although they cease mitosis, they may continue to survive for several months in a postmitotic state. Thus this definition tends to be a bit imprecise as an understanding of when the cells actually die, and the relation of cessation of mitosis to actual death remains incomplete.

The third sense of cell death is physiological cell death, variously referred to as active cell death, programmed cell death, or apoptosis. The latter two terms are slightly different but are often considered to be synonymous. Programmed cell death was first described in 1964 in an embryological or developmental context and referred specifically to the identification of a sequence in which a cell destined for death could be observed to mature metabolically toward its fate long before it was committed to that fate. When it was later recognized that programmed cell death could often be prevented by inhibiting protein synthesis, the implied assumption of a genetic control became more explicit, and the first clear identification of a genetics of cell death, in the ascarid worm *Caenorhabditis*, brought the research into the field of molecular biology.

Limited Life Span of Cells in Culture

During the late 1950s and early 1960s, Harry Eagle developed a culture medium that marked the beginning of an era of well-documented maintenance of cells *in vitro*, and it finally became possible to analyze the potential of cells to reproduce and differentiate without the influence of other cells or fluctuating hormones and growth factors or circulation. In 1961, Hayflick and Moorhead reported that, although they had tried all logical parameters, they were unable to maintain normal diploid human cells, as opposed to cancerous cells, in indefinite culture. The medium was adequate to the extent that it supported vigorous growth of younger cells, but no strain of cells survived longer than 50 ± 10 population doublings. (In their terms, a population doubling was regrowth following a 1:2 subdivision of the culture.) This limitation appeared to be consistent among numerous newly started cell lines. Furthermore, cell lines started from fetal or infant tissue survived longer than lines started from elderly individuals, and cell lines started from short-lived animals survived fewer population doublings than lines from long-lived animals. They therefore postulated that there was an intrinsic limit to the life span of normal cells in culture, and that this limit might contribute to the inability of individuals to survive indefinitely. This laboratory contributed the cell lines to the research community. Of these lines, the WI-38 line (for Wistar Institute, where the culture was established) became a national resource material, as did another line, MRC-10 (Medical Research Council, from England). The research that generated from laboratories using these and similar lines of cells has profoundly influenced gerontology. The major principles that have been developed as of 1995 are as follows:

1. When vertebrate cells are cultured, all normal lines of cells show intrinsic life spans. Transition to immortality is typically a sign that the culture has become equivalent to malignant cells.
2. The number of divisions that cells can undergo decreases with the age at which the explant is taken. In genetic diseases often considered to be cases of premature senescence, such as progeria and Werner's syndrome, cells cultured from affected individuals often show extremely restricted potential for reproducing. In these specific cases,

however, the primary defect may specifically affect the fibroblastic cell types that are usually cultured, and the argument may therefore be tautological.

3. The potential for reproduction of fibroblasts such as WI-38 or MRC-10 cells vastly exceeds the number of fibroblasts that can reasonably be expected to be produced in a normal life span. Therefore, it is unlikely that any individual suffers specifically from a lack of fibroblasts. For erythroblasts (the progenitors of red blood cells) and the precursors of thymocytes and peripheral lymphocytes, however, serial transplantation experiments suggest that the limit may be reached if the tissue is transplanted through only a few generations. It is possible, therefore, that the notable decline in function of the immune system, which renders many elderly individuals incapable of resisting infection, is at least partly traceable to their inability to produce immunologically competent cells (*see* Immune System).
4. Failure of the cells to continue to divide does not mean that they have died. In many instances, cells that have ceased to divide can be maintained for many months in culture. The fibroblastic cells that have become postmitotic have differentiated into a different type of cell. This differentiation has attracted the attention of many top researchers. The decision to opt out of mitosis involves several components, including active suppression of mitosis, inactivation of genes that normally initiate a cell division, and the loss of expendable DNA at the tips of chromosomes. (Because of the mechanics of reproduction of DNA, the last little tip at the end of the chromosome is lost with each cell cycle. Organisms compensated for this problem by starting life with a long stretch of meaningless, or non-coding, DNA, called a telomere. When cells use up this telomeric DNA, they lose the ability to divide. Cancerous cells achieve immortality in part by activation of an enzyme called telomerase, which can restore the missing piece.) (*See* DNA and Gene Expression.)
5. Cells in culture that have ceased to divide finally die by an independent process that is thought by many to be equivalent to apoptosis. These cells may signal their fate by activation of specific genes, one of which is called terminin, and which may be seen in many dying cells.

Cell Death *in Vivo*

In spite of the elaborate and frequently exciting cell biology generated by the study of cells maintained in culture, most losses of cells in the body are maintained in culture, most losses of cells in the body are not related to failure of stem cells to continue to divide but are either accidental necrotic deaths, as when cells distal to a clogged artery die from asphyxiation, or the deliberate suicide of cells under stress or deprived of supporting growth factors or hormones. These two types of death, necrosis and physiological cell death, comprise the bulk of the losses considered to be important manifestations of aging.

Programmed Cell Death

The term physiological cell death is a more general description for two terms that are commonly used in the literature: programmed cell death, which implies a specific causal sequence, and apoptosis, which refers to the mechanics and morphology of the death of the cell. Programmed cell death has an obvious morphology or morphologies and specifically differs from necrosis, in which cells, deprived of energy for any reason, ultimately lose control of ion and solute migration across the cell and mitochondrial membranes, imbibe water and calcium, and lyse.

Apoptosis

The morphologies vary somewhat including a graded series of changes, but they tend to group into two major types: one in which the cytoplasm is heavily consumed by autophagic (lysosomal) activity; and a second, common to many vertebrate cells, in which cytoplasmic changes are relatively modest, but nuclear changes are early and dramatic, including coalescence and margination of chromatin, followed by shrinkage of the cell and degradation of DNA in a characteristic manner. DNA is cut between proteins called nucleosomes that bind to it at regular intervals, so that when the cut DNA is separated by size in a process called electrophoresis, the different size classes of DNA line up in a distinct ladder-like pattern. (In an uncontrolled degradation of DNA such as that seen in necrosis, the DNA is cut at random intervals, and the electrophoretic pattern is that of a smear.) The latter, non-lysosomal, type of physiological cell death technically fits the definition of apoptosis. These points are illustrated in **Table 1** and **Figure 1**.

Programmed Cell Death

The concept of genetic programming of cell death was inherent in the recognition that specific regions of embryonic cell death differed among species, for instance that there were patches of cell death in the interdigital regions of the foot palettes of chick embryos, but not in the corresponding regions of foot palettes of web-footed birds such as ducks. Similarly,

Table 1 Characteristics of different types of cell death

Characteristics of necrosis
- Proximate cause of failure is insufficient energy to maintain ionic pumps
- Cause of failure usually involves masses of cells rather than individual cells
- Calcium enters mitochondria and precipitates. Mitochondria swell and lyse
- Cell loses osmotic control, swells, and lyses, releasing intracellular products
- Inflammatory response ensues and cell is destroyed and consumed by phagocytes
- In general, there is no evidence that the cell has time to respond to the challenge or makes any effective response

Characteristics of programmed cell death
- Stage at which cell is deteriorating but death is reversible
- Often best illustrated by developmental or metamorphic events
- Blocked, at least temporarily, by inhibition of mRNA or protein synthesis
- Cell condenses; nucleus condenses at varying times
- Consumption of cell by autophagocytosis or by phagocytosis

Characteristics of apoptosis
- Early nuclear condensation and margination of chromatin
- Fragmentation of nuclei into several pieces
- Fragmentation of DNA as detected by electrophoresis or *in situ* end labeling
- Typically, condensation of cytoplasm with no activation of lysosomes
- Alteration of cell surface proteins
- Phagocytosis by non-professional phagocytic cells (neighboring cells)

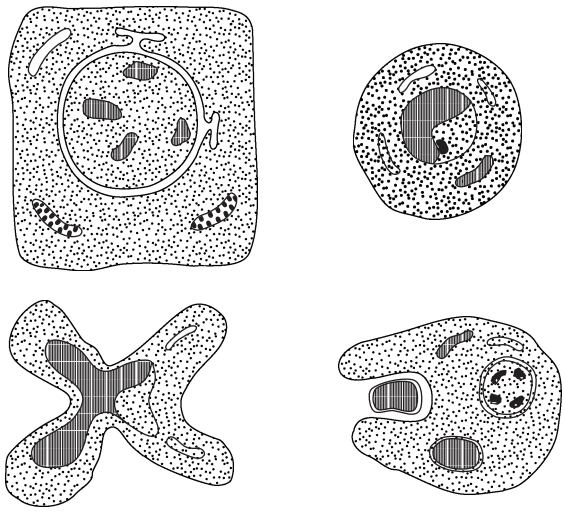

Figure 1 Schematic of changes occurring during apoptosis. In the upper left, a normal cell displays a round nucleus with occasional chromatin patches, an endoplasmic reticulum budding off the nucleus, and mitochondria. During early phases of apoptosis (upper right) the cell rounds and shrinks, while the chromatin aggregates against the nuclear membrane. Other organelles remain intact. The apoptotic cell then fragments into small membrane-bound particles (lower left), which may or may not include portions of the nucleus. Finally (lower right), in cells within the body, the fragments are engulfed by macrophages or by neighboring cells.

certain teratological abnormalities traceable to single genes were thought to derive from abnormalities of cell death. However, the humble ascarid worm *Caenorhabditis elegans* contributed the first unequivocal documentation for a genetics of cell death. In this organism, the origin and fate of each cell is known, and approximately 15% of the cells in the embryo are born only to die shortly thereafter. Several laboratories through assiduous efforts demonstrated that a small number of genes controlled the death of these cells. These genes function at several levels: two classes of genes are necessary, along different pathways, for cells to die, and one class prevents the death of these cells. A fourth set specifies which cells are supposed to die, and others regulate the phagocytosis and digestion of the corpses. The sequence is illustrated in **Figure 2**. A similar sequence is likely to exist in *Drosophila*, where a gene responsible for controlling numerous embryonic cell deaths has been found to exist.

These genes have homologs among mammals. Most notable are the following: the cell death prevention gene *ced-9* is homologous to a mammalian gene, *bcl*-2 (B cell lymphoma-2), which prevents the death of B lymphocytes. These surviving lymphocytes may eventually turn malignant. One of the genes necessary for the death of the *Caenorhabditis* cells is homologous to a specific protease, which is itself required in several experimental forms of cell death. Also in mammals, a gene known to be important in preventing the expansion of tumors, *p53*, acts in a manner similar to that of the cell death genes. Most interesting, in both mammalian cells in culture and in *Caenorhabditis* the anticell death genes *bcl*-2 and *ced-9* may under some circumstances be experimentally exchanged, and variants of the cell death-inducing protease family may likewise be exchanged. Thus it is fair to assume that the mechanisms of cell death have been highly conserved in evolution and that similar processes operate in mammalian cells. As is described below, many other genes may be upregulated in different instances of cell death. However, since causality has not been established and our understanding remained fluid in 1995, excessive attention to many of these genes was not considered appropriate (*see* Models of Aging: Vertebrates).

Apoptosis

Degradation of the Nucleus

The common morphology of dying cells is not yet fully explained. Although there are several well-understood mechanisms that can explain the swelling

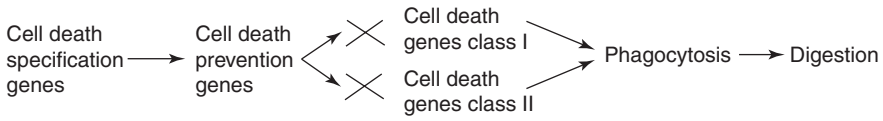

Figure 2 Sequence of control of cell death in *Caenorhabditis*. In order for cells to die by apoptosis, they must contain members of two classes of cell death genes, one of which appears to be a protease. All or most cells are capable of activating these genes, but the death program is suppressed by a cell death prevention gene that is similar to a mammalian oncogene. During development, the cell death prevention gene is turned off in specific cells, allowing the programmed developmental deaths of unique cells. Cells that die are finally phagocytosed by other cells, requiring genes for recognition of the dead cell, nucleases, and perhaps other enzymes.

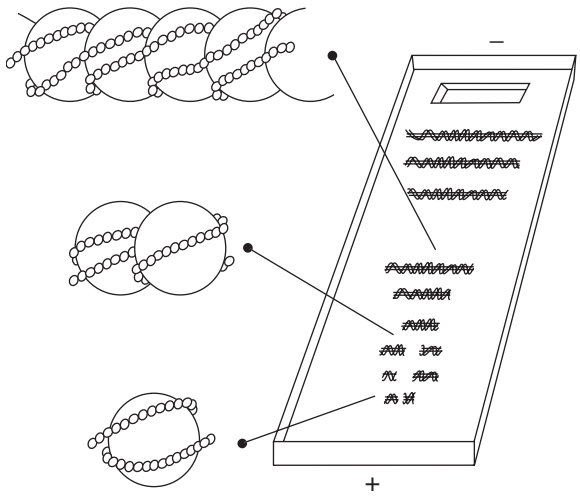

Figure 3 Origin of the hallmark DNA ladder. In normal eukaryotic cells, DNA helices are wound around aggregates of basic proteins (histones). These aggregates are consistent in size and are termed nucleosomes. The DNA in the gap between each nucleosome is more readily digested by certain nucleases than are the approximately 180 base pairs of DNA directly on the nucleosome, breaking the DNA into discrete units differing in size by approximately 180 base pairs. When DNA is electrophoresed or driven by an electric current through an agarose gel, the smaller pieces move more rapidly. Thus, in apoptosis, a distinct 'ladder' of DNA is formed. In necrotic cell death, digestion of DNA is far less organized and a smear rather than a ladder is formed.

and bursting of a necrotic cell, it is more difficult to explain the shrinkage and changes of nuclear morphology that are common to cells dying by apoptosis. Characteristically, the earliest changes are a rapid coalescence of chromatin and its collection along the nuclear membrane. These are frequently associated with degradation of DNA at specific points (**Figure 3**) by an enzyme that may be already resident in the nucleus, suggesting therefore that changed conditions in the cell or in the nucleus allow the enzyme to attack the DNA. Other evidence, however, argues against the idea that cleavage of DNA to nucleosomal fragments is a critical step in apoptosis. Several laboratories have detected damage to DNA prior to its degradation to nucleosomal size, including its release from the nuclear membrane by a possibly proteolytic cleavage. Other research indicates that the morphology and the degradation of DNA may be dissociated, whereas arguments and data from several sources suggest that damage to DNA does not immediately kill the cell. Thus, although the specific destruction of the nucleus may be a hallmark of apoptotic cell death, its origin and significance remain mysterious.

Cell Shrinkage

The second salient characteristic of apoptosis is shrinkage and condensation of the cell, while organelles and cell membrane remain intact. It is not easy to explain this process. In order for a cell to shrink, it must extrude water. Because other cells in the vicinity, unaffected by apoptosis, remain of normal size, the osmotic tension of the extracellular fluid presumably has not changed. Therefore, only three mechanisms are available for it to lose water. It must decrease intracellular solute; it must develop a contractile force sufficient to extrude water against osmotic pressure, or it must actively extrude solute, with water following. It might decrease intracellular solute by cross-linking, polymerizing, or precipitating proteins. The cytoskeleton provides the only known means of contractile force in the cell, and it is doubtful that it can generate the force necessary. One can get an estimate by assuming the cell to be a cube with a striated muscle shortening one dimension. Because most muscles can generate a force of approximately $5\,kg/cm^2$, and it would take a force of approximately $2\,kg/cm^2$ to maintain a volume reduction to half the original cell size, a cell would need a density of cytoskeleton approximately half the density of myofilaments in a striated muscle, with the contractile force of the muscle, to account for the collapse of the cell. Although this force is of the right order of magnitude, it does not appear to be the most logical explanation for the collapse of the cell.

An alternate explanation is cross-linking or precipitation of proteins. There is currently no evidence that the highly condensed proteins are precipitated or insoluble. Proteins cross-linked by transglutaminase are common in many apoptotic bodies, suggesting that cross-linking may play a role in the shrinkage of the cell.

Phagocytosis (Cell Surface Proteins)

Because one characteristic of an apoptotic cell, at least one found in an organism as opposed to one in culture, is that it is phagocytosed by a phagocyte or, more frequently, by a neighboring cell that previously was not considered to be phagocytic, the surface of the attacked cell must carry some markers that identify it as apoptotic. Some of these markers have been identified. Some represent glycoproteins known previously to have been on the surface but now more exposed or exposed in different orientation because of the rearrangement of the cell membrane. Others may identify specific cells as apoptotic and ripe for consumption. Loss of sialic acid from membrane carbohydrates, appearance of phosphatidyl serine on the cell surface, and binding of cell surface receptors all play roles in phagocytosis in specific instances. This targeting is sufficiently effective that the growth of tumors expressing it can be forced to regress by appropriate manipulation of the gene. Another example is fas ligand (FasL), a cell surface protein related to tumor necrosis factor and expressed primarily in activated T cells. Fas is produced by several types of cells. Binding of fas to its ligand induces apoptosis, and failure of the interaction may lead to autoimmune diseases and other immunoproliferative disorders.

How a Cell Dies

The mechanism by which a cell dies a physiological death is not yet well understood. Signaling mechanisms frequently involve growth stimuli or sudden withdrawal of growth stimuli in otherwise congenial environments, and the first responses of cells about to undergo apoptosis are related to those of cells about to reinitiate mitosis. In cells that are subject to many influences, several laboratories have documented that the paths to apoptosis are typically at least partially independent, recalling the dual sets of genes required for cell death in *Caenorhabditis*. Typically, energy resources in a doomed cell remain adequate, and cell and mitochondrial membranes remain intact, until substantial damage has been done to the cell; the irreversibility of death, which tends to be coincident with massive morphological and biochemical damage, is established at a later time than the commitment to the death pathway. These several observations led to the conclusion that cell growth and cell death are tightly linked. For instance, many of the genes activated in growing or dividing cells are proto-oncogenes. Proto-oncogenes are important in the initiation of cell growth or cell division. They owe their names to the fact that they are occasionally captured by viruses. In this virus, they are separated from the controlling genes that typically reside next to them on normal chromosomes, and they therefore cause uncontrolled growth or cancer. One of these proto-oncogenes, *c-myc*, is also activated in many forms of cell death. *c-myc* is well enough known that the exact structure of the gene has been established, and only very limited areas of the gene, a few basepairs in length, actually control the oncogenicity. This precise region of the gene is also influential in apoptosis, suggesting that the product of the gene can stimulate the growth of the cell under some circumstances and can stimulate cell death in other circumstances. A general image of how cell death occurs may be that numerous factors are required for a cell to complete the complex process of growth or mitosis and that, if any of the factors are unavailable, the cell will die.

Cell Death in Aging

Organisms do not die from programmed cell death or apoptosis. Although the limited life span of cells in culture suggests that a decrease in cell division may contribute to decreased function in immunodefense and maintenance of the epidermis, erythroblasts and intestinal crypt cells do not approach their mitotic potential in a normal life span. For postmitotic cells such as neurons and muscle, the consequences of physiological cell death are more important, and because in tumors cell death is a major factor determining the expansion of the malignancy, interest in cell death is high. The most important areas relating gerontology and aging are the following.

Malignancy

Several lines of evidence indicate that cell death is a factor in malignancy. In many tumors, the rate of cell death is a better indicator of malignant potential than is the rate of cell division. Dietary restriction, the only known means of extending life span in mammals, may increase the rate of apoptosis. The *bcl*-2 oncogene acts by inhibiting cell death, and other genes such as *Apo*-1 regulate the rate of apoptosis in a tumor. These observations by themselves argue that study of cell death should be of interest to oncologists. Another consideration is that most chemotherapeutic techniques attempt to kill mitotic cells. In doing so, they necessarily damage other normal but highly mitotic tissues, such as intestinal epithelium, lymphocyte stem cells, and epidermis, as well as cells with high metabolic demands, such as liver and neurons. A chemotherapeutic approach attempting to induce apoptosis in tumor

cells promises to be far less toxic, or minimally to deflect toxicity from normal mitotic cells. (*See* Cancer and Age.)

Gradual Cell Loss

Perhaps the most important suggestion is one derived from a current sense of the biology of apoptosis. As mentioned in the previous section, there is a curious relationship between growth stimuli and responses and apoptosis. Several laboratories have detected homologies between receptors for growth factors and receptors that, when activated by binding a product, trigger cell death. Similarly, as many cells respond to stimuli that will lead to their death, genes normally associated with growth responses, including those required for cell division, are up-regulated. One or more of these genes, such as several cell cycle genes (which are up-regulated during specific phases of cell division) and oncogenes (genes frequently normally used in cell division, which by uncontrolled regulation can cause cancer or cancer-like transformations) are activated in an aberrant manner, and restriction of the activity of these genes may prevent the death of the cell. One interpretation of these results is that the dysregulation is itself a signal, and that cells are programmed to self-destruct if all growth-regulating stimuli impinging on the cell are not completely consistent with the ability of the cell to respond. Particularly among cells that can still undergo mitosis, such a response would be a powerful defense for the organism against potential malignancy. There is at least one claim that the rate of apoptosis declines with age. A low rate of apoptosis could preserve cells but could also heighten the risk of cancer.

Deliberate Self-Destruction in the Immune System

As is described above, cell death in the differentiating immune system is delicately balanced to ensure a wide variety of immunocompetent cells, resting in reserve against a nearly infinite variety of possible antigens, without either attacking self or, by multiplying, draining resources when not needed. The complexity of the controls and stimuli needed to maintain a primary T- or B-lymphocyte is very great, involving a delicate balance of interactions between antigens presented to the cell at specific stages in the differentiation of the immunologically competent cell and the ability of the differentiating and stem cells to recognize those antigens. The complexity may be required to assure the destruction of cells that may form antibodies against one's own body. Other functionally important exploitations of the ability of cells to die are self-destruction of a cell infected by viruses to limit replication of the virus, and self-destruction of a cell that, by virtue of damage to its DNA (mutation) threatens to become cancerous. Among the several steps that cells take toward carcinogenicity, loss of sensitivity to signals to die is an early and ominous one. Nevertheless, the salubrious loss of cells in such circumstances likely contributes to the gradual deterioration of immunocompetence with aging. In a chronic viral infection, for instance, huge numbers of immunocompetent cells may be generated, but a slight imbalance between generation and loss will lead to such a gradual deterioration. Such an imbalance may be seen, for instance, in the progression of acquired immunodeficiency syndrome (AIDS) by gradual loss of specific immunocompetent cells over a 10-year course (representing a net imbalance of 0.03% per day between loss and replacement) or in the difference between imunologically competent centenarians and their less fortunate cohorts. Similarly, an imbalance of 0.004% between the birth and death of hundreds of millions of cells per day could reduce the number of immunocompetent cells by half by the end of an average lifetime. What is startling is that the balance is so precise. As we learn to understand how these controls trigger cell death, we are likely to develop cell death-based therapies either to maintain immunocompetent cells or to prevent autoimmunity, both complications of aging.

Loss of Postmitotic Cells

Loss of postmitotic cells, especially in the CNS, remains a threatening aspect of aging. Many of these losses appear not to be necrotic, derived from circulatory failures, but rather a physiological death of a cell strained beyond its limit. It has become evident, for instance, that loss of cells even in stroke may be by apoptosis, suggesting that cells undergo a prolonged period of agony during which they might conceivably be rescued. A major molecular product generated in senile dementia of Alzheimer type (SDAT), an oxidized form of the β-amyloid accumulated in the disease, is toxic to neurons and, in culture at least, they display such signs of apoptosis as up-regulation of specific oncogenes and protection by experimental activation of the antiapoptosis gene *bcl*-2. Therapeutic considerations remain theoretical. It is likely that the cells that eventually die do so after having passed a considerable period of agony, since postmitotic cells are frequently more resistant to apoptosis than are rapidly replaced cells. Such an explanation would account for the late onset of cell loss in SDAT as well as for other losses less directly attributable to disease. One presumes that the agonizing cell is identifiable before it succumbs and, as in programmed cell death,

passes through a reversible phase. Here a therapeutic goal is to identify the agonizing cell, identify what aspect of its support is inadequate, and to intervene to stabilize it before it dies (*see* Brain and Central Nervous System; Dementia).

See also: Brain and Central Nervous System; Cancer and Age; Dementia; DNA and Gene Expression; Immune System; Models of Aging: Vertebrates.

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Cellular Aging: Growth Factors and Cellular Senescence

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Glossary

Growth Factors – Small proteins that bind to specific receptors on the surface of cells. The activation of these receptors drives DNA synthesis to produce a replicate copy of the genome, increased protein synthesis, and an increase in cell size and cell division.

Hayflick Limit – The limit to the proliferative life span of normal cells in culture.

Senescence – When cells lose their ability to divide and enter a nondividing state in which cells enlarge and remain viable for long periods, but they are unresponsive to conditions that would trigger their division when they are 'young' or freshly isolated from the body.

Telomeres – DNA at the end of each chromosome.

Introduction

Human cells have a limited life span when removed from the body and placed into cell culture. This limited life span has been used to study processes associated with aging in a controlled environment in the hope that the mechanisms associated with the aging of cells in culture will provide insight into aging of

the whole organism. Cell culture provides an environment in which multiple variables can be carefully controlled and cell responses can be examined at the molecular level. A great deal of work regarding the aging of human cells *in vitro*, i.e., in cell culture, has been done with human fibroblasts.

When human fibroblasts are removed from the body and placed into cell culture, the cells will divide rapidly when provided with proper nutrients and growth factors. However, following this period of rapid division, fibroblast cells begin to 'age' *in vitro*. This aging process is driven by cell division. As the fibroblasts age, the cells lose their ability to divide and enter a non-dividing state in which cells enlarge and remain viable for long periods, but they are unresponsive to conditions that would trigger their division when they are 'young' or freshly isolated from the body. This non-dividing state is termed senescence and was first described by Leonard Hayflick; the limit to the proliferative life span of normal cells in culture is often referred to as the Hayflick limit. It is important to point out that cell lines derived from cancerous tumors do not display this Hayflick limit and will divide indefinitely. Similarly, normal cells can be induced to bypass the Hayflick limit through the introduction of specific viral proteins. These proteins have multiple functions, but at least one function that is known to be required for the abrogation of the Hayflick limit is the inactivation of p53, a critical regulator of cell response to DNA damage. A particular line of fibroblasts isolated from a skin biopsy will display a reproducible number of cell divisions before reaching the end of its life span and entering senescence. This indicates that there is some reproducible mechanism that underlies the eventual growth arrest or senescence of these cells.

An important point is that rodent cells will spontaneously avoid the Hayflick limit and develop into so-called 'immortal' cell lines similar to cancer cell lines. In fact, recent work indicates that if damage to the cells produced by oxygen can be limited, rodent cells do not exhibit a limited life span and simply divide indefinitely.

What Causes Senescence?

Although many possible explanations for the mechanism that underlies the Hayflick limit have been proposed, it is still not clear what triggers the irreversible growth arrest seen in senescent cells. A loss of telomeres, DNA at the end of each chromosome, has been considered an attractive candidate for the senescent trigger. The hypothesis was that a small amount of the telomere at the end of the chromosome (which is linear) is lost at each cell division due to the directionality of DNA polymerase. DNA polymerase can completely replicate one strand of DNA but cannot begin at the very end of the opposite strand. It needs a small length of primer to begin the replication process, and thus a small amount of DNA is lost at each cell division. This incremental loss of telomere DNA provided an attractive explanation for the Hayflick senescent limit that matched a great deal of experimental evidence. For example, careful studies showed that it was the number of cell divisions, not the length of time in culture, that dictated the Hayflick limit. The loss of telomeres correlated nicely with this information.

Similarly, rodent cells have very long telomeres, suggesting that they would be much less susceptible to a limit to cell division dictated by telomere length. This fits nicely with the ability of rodent cells to evade the Hayflick limit. However, as the telomere structure and dynamics were examined more closely, it became clear that the simple idea that a bit of DNA was snipped off at each division and this eventually caused the cells to stop dividing was not true. One of the first indications that the telomere story was more complex than first thought was that some tumor cell lines survived quite well with very short telomeres. Also, it became clear that telomeres are assembled into complex structures through the interaction of multiple proteins. It was the disruption of these complexes, rather than the loss of telomere DNA per se, that could induce cell arrest. Furthermore, it became clear that many normal cells had the ability to increase their telomeres. This was not originally understood. The initial thinking was that telomere sequences could not be replicated by normal cells.

In the final analysis, it is still not clear what triggers the senescent arrest. It could be that telomeres are involved, and it is fairly certain that regulators of the cell cycle such as p53 and p16 are involved. Interestingly, it has recently been realized that mutations in critical genes involved in cell division may induce a senescent arrest. This has been shown clearly in the case of a gene known as *RAS*. Mutations in the *RAS* gene are quite common in human cancers, and these mutations cause an increase in the activity of the protein. The Ras protein is a central regulator of cell growth, so its activation is thought to be important to the growth of cancer cells. Interestingly, when a mutated *RAS* gene is introduced into normal cells they do not divide more rapidly, as would be expected if they were making the transition to a tumor cell, but rather undergo a senescent-like arrest. This was first observed in the early 1980s when *RAS* was first identified, but the implication of this observation was not fully appreciated until 2001. The presence of a mutated Ras

protein induces the senescent arrest by increasing the expression of specific proteins that regulate cell division known as cyclin-dependent kinase (CDK) inhibitors. As the name implies, these proteins regulate the activity of the CDKs that serve to regulate what is known as the cell cycle. The cell cycle refers to the steps that a cell undergoes during division, growth, DNA synthesis, and cell division. Because this results in the generation of two new identical cells that will undergo the same process immediately if conditions are right, the cell division process is called the cell cycle.

A series of proteins was identified in yeast that are expressed at specific times in the cell cycle; their ordered expression is critical for cell division to occur. These proteins, known as cyclins, are produced by mammalian cells as well and serve a conserved function, to regulate the timing of critical events during cell division. The cyclins bind to, and regulate the activity of, specific proteins within the cell known as CDKs. When activated, the enzymatic activity of a kinase will covalently link phosphate groups from ATP (adenosine triphosphate) to target proteins. ATP is the major energy source for the cell, and this energy is stored in the form of high-energy phosphate bonds that facilitate the transfer of the phosphate group to a target protein by the kinase. Inhibitors of cyclin function, the CDK inhibitors, have been identified. Senescent human cells produce high levels of two of these CDK inhibitors, known as p16 and p21 for their molecular weight. Introduction of these inhibitors into young early-passage cells will induce a senescent-like arrest, and cells that have lost p16 are not arrested in response to a mutated Ras. Thus, it is clear that these inhibitors play a critical role in the senescent arrest.

In addition, several laboratories have shown that a senescent-like growth arrest can be induced in response to several types of manipulations such as increasing the level of ceramide in the cell membrane or blocking growth signals. The upshot of these observations is that the senescent arrest may represent a common endpoint that can be triggered in response to several different disturbances in cell function.

Senescence and Growth Factors

One approach to understanding the senescent growth arrest is to examine the factors that are required for the division of young cells and to determine whether the senescent cells are able to respond to these factors. Any defect in their response would presumably shed light on the mechanism of the growth arrest.

In virtually all cell types, cell division is regulated by the presence of growth factors. Growth factors are small proteins that bind to specific receptors on the surface of cells. The receptors for growth factors contain intrinsic enzymatic activity that is activated by growth factor binding. The activation of these receptors produces a cascade of enzymatic events within the cells to drive a number of events, including DNA synthesis to produce a replicate copy of the genome, increased protein synthesis, and an increase in cell size and cell division. Understanding the factors that drive cell division in general was an area of great interest in the 1960s through the 1980s. Investigators used the fibroblast cell as the model system of choice due to the reproducible way in which these cells would divide following a period of nutrient deprivation. Fetal bovine serum, added in small quantities to a nutrient medium, was found to contain the strongest mix of factors for fibroblast cell division. Laborious work identified the key factors contained in fetal serum that are required for initiating cell division as a growth factor known as platelet-derived growth factor and two closely related proteins known as insulin-like growth factors. As its name implies, platelet-derived growth factor is released by platelets during the clotting process and is contained in serum but is absent from plasma. The insulin-like growth factors are two closely related proteins, insulin-like growth factor 1 and insulin-like growth factor 2. The insulin-like growth factors are produced by the liver and other tissues under the control of growth hormone.

Over time, a number of growth factors have been isolated. They can be grouped into two classes based upon their role in regulating cell division. The first class of growth factors, termed initiation factors, which includes platelet-derived growth factor, is required for initiating cell division in resting cells. The function of these growth factors in terms of cell division (it should be mentioned that the growth factors regulate many aspects of cell behavior such as motility in addition to regulating cell division) is to move a cell out of the resting or quiescent state. The quiescent cell is performing differentiated functions producing proteins specific to its class, and the initiation factors serve to shift the cell away from these differentiated functions and toward cell division. But they are not sufficient to drive cell division on their own.

The second class of growth factors, collectively known as progression factors, includes the insulin-like growth factors and is required at a later stage for the initiation of DNA synthesis and cell division. In general, cells require the addition of two growth factors, one initiation factor and one progression factor, to divide. The specific growth factor that regulates division in a specific cell type is dictated by the cell surface receptor that the cell produces. Like a

lock and key, only the right growth factor will activate a specific receptor. For example, no other growth factor can substitute for platelet-derived growth factor in terms of activating the platelet-derived growth factor receptor. Thus, a cell expressing the platelet-derived growth factor receptor and the insulin-like growth factor receptor will respond to this specific combination.

Senescent Cells are Not Defective in Terms of DNA Synthesis

Senescent cells are unable to respond to the growth factors that drive cell division in young cells. However, a series of key experiments demonstrated that introduction of the viral proteins that will allow rodent cells to bypass the Hayflick limit into human cells will cause the cells to replicate their DNA once and then arrest again. Human cells will not totally bypass the Hayflick limit, but will undergo a single round of DNA synthesis. This is important because it means that the senescent cells are fully capable of dividing, but that there is some intrinsic block to cell division that prevents signals generated by growth factors from initiating cell division. A further implication is that the identification of the mechanisms of the block to growth factor signals would provide insight into the causes of senescence, which is potentially a source of aged cells in the body.

Why do Senescent Cells Fail to Respond to Growth Factors?

Although the evidence is not complete, it seems that the reason that growth factors are unable to drive cell division is that the enzymatic cascade activated by the binding of a growth factor to its specific receptor on the cell surface does not translate into the nucleus. A highly complex series of protein–protein interactions is initiated when a growth factor binds to its cognate receptor. The majority of growth factor receptors possess intrinsic kinase activity, critical to their function, that is activated upon binding of a growth factor. Once activated by growth factor binding, growth factor receptors will use the energy bond in the phosphate bonds of ATP to transfer one phosphate from ATP to a target protein. The sites of this transfer within the target proteins are very specific and have been precisely mapped in many cases. The result of these phosphorylation events is a change in the conformation of the target protein, generally producing an unfolding, since the phosphate group has a negative charge. The conformational change can produce one of several responses in the target protein. An intrinsic enzymatic activity (often also a kinase activity) can be activated. Alternatively, the unfolding may expose parts of the target protein that were previously buried to facilitate specific interactions, or new phosphorylation sites may be exposed. In addition, the phosphorylated target proteins often serve as docking sites for other proteins that recognize the phosphorylation site only when the phosphate group has been attached. This allows the assembly of multi-protein, multi-enzyme complexes that result in the activation of many hundreds of proteins within the cell. This produces a wave of response that affects multiple cellular functions.

In senescent cells, it has been found that the movement of proteins from the cytoplasm into the nucleus is reduced. In addition, it seems that the wave of protein activation initiated by growth factors also has trouble crossing into the nucleus. The result of this block to activation of nuclear responses is that genes essential for cell growth and division are not turned on at the appropriate time. This produces a situation in which the cell completes most, but not all, of the required steps for cell division. For example, the cells will increase in size (senescent cells are known to be abnormally large) but do not replicate their DNA. The end result of this incomplete response is that the cell will stop in an attempt to affect repairs. Since no repairs can be made, the cell must either die or remain in a frozen state. It is this non-dividing frozen state that is the hallmark of the senescent cell. Senescent cells have been maintained for several years by rather stubborn scientists without a loss of viability. This long-term survival is in marked contrast to the response of cells derived from cancerous tumors. The majority of cells that have been studied in culture are tumor cells, which do not display a senescent arrest. Tumor cells will undergo a programmed death if they are not able to complete all the steps required for cell division. This programmed cell death (known as apoptosis) is the basis for most chemotherapy. For example, the use of radiation to treat cancer relies on the fact that the DNA inside cells is broken by the high levels of radiation. Tumor cells divide very rapidly and cannot completely replicate their DNA when radiation damage is present. This triggers programmed cell death. However, the senescent cell is resistant to radiation damage and will not die if exposed to levels of radiation that would kill a tumor cell.

Consequences of the Senescent Arrest

Senescent cells lose the ability to perform normal cell functions but remain viable. It has been suggested that the presence of viable cells that have undergone

a senescent arrest in the tissues of older people will lead to a disruption of normal function in the surrounding area. For example, fibroblast cells normally produce a large amount of extracellular matrix and are important for maintaining tissue integrity. When fibroblasts senesce, the cells no longer secrete extracellular matrix and begin to produce enzymes that can break down the tissue matrix. Theoretically, this will cause a local disruption in the supporting matrix of the tissue. Some investigators have suggested that this may enhance the ability of cancer cells to survive and to metastasize. While the concept that dysfunctional senescent cells alter tissue function is attractive, senescent cells have been difficult to identify in tissues because there is no distinct marker to identify them. There is only one report identifying senescent cells in human tissues, and the marker used for the identification has been tested by other investigators and is not a definitive marker for senescence even though it is consistently produced by senescent cells. This leaves open the question of the presence of true senescent cells in the tissues of older people. No one has been able to verify that senescent cells exist *in vivo,* but given the ubiquitous nature of senescence, it would be very surprising if this type of arrest did not occur in cells as people age.

Summary

The description provided here represents the view of the author and is not representative of all of the viewpoints regarding the senescent arrest. Many investigators would strongly argue that the telomere is the central mediator of the senescent arrest. Others would argue that cell cycle checkpoint proteins such as p53 or the CDK inhibitors are the essential mediators of the senescent arrest. Certainly it is known that p53 phosphorylation is altered in senescent cells. Similarly, it is known that the CDK inhibitors are present at high levels in senescent cells. It is also known that a senescent-like growth arrest can be induced by disrupting p53 activity or introducing CDK inhibitors. However, it is also clear that introducing an oncogene such as RAS will induce a senescent-like arrest, and blocking growth factor signaling will also produce a senescent-like arrest. The major problem is that this produces a chicken and egg conundrum. In senescent cells one can identify specific changes in p53, CDK inhibitor levels, telomere length and conformation, growth factor signaling, ribosome phosphorylation, and protein synthesis, which can all account for the senescent growth arrest. However, each of these changes can just as plausibly be the result of the senescent growth arrest. It is currently impossible to tell which of these changes is the initiator of the senescent arrest and which is the downstream response. In the author's opinion, a key point is that the senescent arrest, or one that bears many similarities to senescence, can be induced by disrupting any one of the critical cellular elements discussed previously. This strongly argues that the senescent arrest represents a default response to cell damage in normal cells. Thus, a normal cell, when faced with DNA damage, telomere erosion, long-term growth factor deprivation, or mutation of a critical gene, will become senescent. It is the universal nature of the senescent arrest and the fact that tumor cells have somehow avoided this critical arrest response that drives the continued interest in senescence. It is clear that understanding the mechanisms of senescence will enormously expand our understanding of basic cellular responses during aging and will certainly have important uses in the treatment of cancer.

See also: Cancer and Age; Cell Death.

Further Reading

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Cellular Signal Transduction

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Glossary

Cross-Talk – Functional interaction between signal transduction pathways.

G-Protein-Coupled Receptor – Member of a large family of cell surface receptors that contain seven transmembrane spanning regions and function through coupling to heterotrimeric guanine nucleotide binding proteins (G-proteins).

Receptor Tyrosine Kinase – Member of a class of cell surface receptors that relay signals through protein-tyrosine kinase activity intrinsic to the receptor.

Second Messenger – An intracellular signaling molecule generated in response to an extracellular signal.

Signal Transduction – The biochemical events through which extracellular signals are transmitted into cells and converted to physiological responses.

Transactivation – The process by which a G-protein-coupled receptor activates a receptor tyrosine kinase.

Introduction

Postmaturational aging and senescence are accompanied by losses of physiological function, decreased maintenance of homeostasis upon exposure to a variety of stressors, and the emergence of age-associated diseases. Many of the physiological and pathophysiological changes occurring with advanced age may reflect alterations in the coordinated responses of diverse tissues and cells to environmental or intrinsic perturbations. Normal function and even survival of all complex organisms are dependent on the integrity of an intercellular communication system requiring individual cell types to exhibit appropriate biological responses to extracellular stimuli. The term signal transduction is used to describe the biochemical pathways through which extracellular signals are transmitted into cells and converted to physiological responses. In the classical model of signal transduction, binding of an extracellular signal (e.g., a peptide hormone or neurotransmitter) to a specific receptor on the cell's outer or plasma membrane triggers a process leading to the generation of an intracellular signaling molecule, or second messenger, which then initiates so-called downstream signaling events to elicit a cellular response. Relatively recently, the field of signal transduction research has been extended to the elucidation of non-classical signaling pathways underlying the mitogenic actions of growth factors and related processes controlling tissue morphogenesis, maintenance, and regenerative capacity. Moreover, fundamental advances continue to be made in the understanding of the signal transduction pathways responsible for the actions of steroid (and thyroid) hormones, which in the traditional view act exclusively through intracellular receptors but which have also been found to activate membrane-associated signaling cascades. Despite this complexity, the demonstration of cross-talk, or functional interaction, among many individual signaling pathways has to some extent provided a unifying framework for the vast network of messages now recognized to control diverse cellular functions.

Over the years, numerous elements of signal transduction pathways have been examined descriptively with respect to changes during aging; only to a lesser extent have emerging concepts of cellular signaling been applied to questions of aging physiology and pathophysiology. Nonetheless, available data summarized here indicate that functional decline during aging and the development of age-associated diseases are in some instances clearly linked to specific alterations in cellular signal transduction.

Classical Signal Transduction and Aging

Classical Signaling Mechanisms

Among cell surface receptors linked to classical signaling pathways, the largest family is composed of receptors that contain seven transmembrane spanning regions and function through coupling to heterotrimeric guanine nucleotide binding proteins (G-proteins). Upon binding of extracellular signals, or ligands, these G-protein-coupled receptors (GPCRs) function to activate or inhibit specific membrane effectors. The classical example of a membrane effector is the adenylyl cyclase enzyme, which when activated generates the prototypical second messenger cyclic AMP from ATP. Other GPCR-linked effectors include the phospholipase C (PLC) enzyme, which cleaves membrane phosphoinositides to produce the signaling molecules 1,2-diacylglycerol

and inositol 1,4,5-trisphosphate, and membrane ion channels. Of note, GPCRs represent the largest number of pharmacological targets for therapeutic drugs in current use.

Intracellular second messengers elicit diverse, often cell type-specific, physiological responses mediated in many cases by protein kinase enzymes, which modify the activities of critical target proteins by phosphorylation (phosphate group addition) on specific amino acid (serine and threonine) residues. For example, in mammalian fat cells cyclic AMP increases lipolysis, the process by which triglyceride lipid is hydrolyzed to free fatty acids and glycerol, by stimulating a specific protein kinase (cyclic AMP-dependent protein kinase, or protein kinase A) that in turn phosphorylates and activates the lipolytic enzyme hormone-sensitive triglyceride lipase (**Figure 1**). Activation of the same cyclic AMP/protein kinase A pathway in liver cells increases glucose production in part via phosphorylation and activation of the enzymes catalyzing glycogen breakdown to glucose (glycogenolysis) (**Figure 2**).

Altered Lipolytic and Glycogenolytic Signaling During Aging

Lipolysis in Fat Stimulation of lipolysis by hormones and catecholamines declines with age in several species, including humans. Numerous studies have been performed to identify the underlying signaling mechanisms responsible for reduced catecholamine-sensitive lipolysis in aging rats. The results of these studies have varied, depending in part on whether the experimental conditions employed were sufficient to discriminate among the actions of multiple GPCRs that either stimulate or inhibit the lipolytic process. In this context it should be noted that in diverse tissues including fat cells, the naturally occurring catecholamines epinephrine and norepinephrine exert both β- and α-adrenergic functions, mediated respectively by distinct β- and α-adrenergic GPCRs. As illustrated in **Figure 1**, β-adrenergic receptors are coupled to a stimulatory G-protein (G_s) that activates adenylyl cyclase and downstream physiological responses such as lipolysis, whereas α-adrenergic receptors (specifically, receptors of the α_2-subtype) exert an inhibitory effect on adenylyl cyclase mediated by an inhibitory G-protein (G_i). In addition, adenosine is normally generated by fat cell metabolism and is known to reduce lipolysis in rats by binding to a specific GPCR that inhibits adenylyl cyclase via G_i. A comprehensive review of the literature on aging and catecholamine-sensitive lipolysis in the rat implicates three biochemical loci along the lipolytic signaling cascade at which the overall stimulatory action of catecholamines is disrupted over the adult life span: (1) enhanced inhibition of adenylyl cyclase by locally produced adenosine during maturation, but not senescence; (2) a probable increase during senescence of inhibitory α-adrenergic receptor-mediated signaling by catecholamines exhibiting both α- and β-adrenergic activities; and (3) a decline during senescence in the stimulatory action of cyclic AMP on hormone-sensitive triglyceride lipase in fat cells from some anatomic sites (e.g., perirenal fat) but not

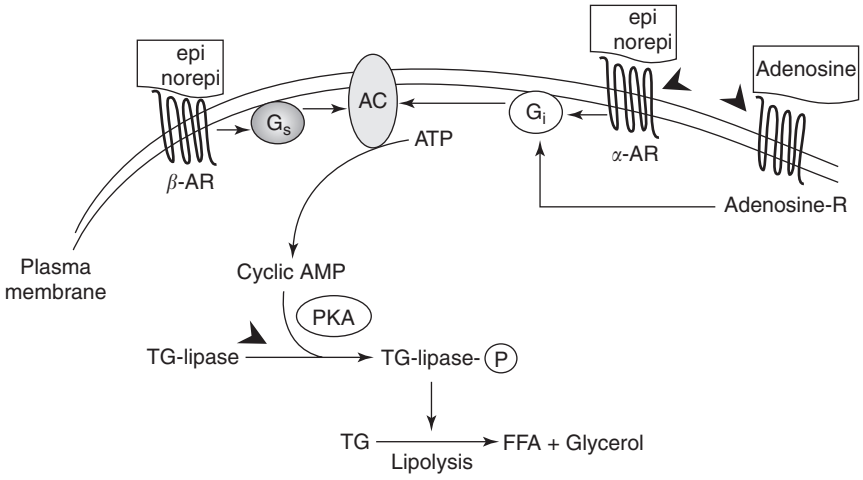

Figure 1 The lipolytic signaling pathway in the fat cell. Arrowheads designate sites at which age-related changes in lipolytic signaling are known to occur (see text). Abbreviations: epi, epinephrine; norepi, norepinephrine; β-AR, β-adrenergic receptor; AC, adenylyl cyclase; G_s, stimulatory G-protein; α-AR, α-adrenergic receptor; Adenosine-R, adenosine receptor; G_i, inhibitory G-protein; TG, triglyceride; PKA, cyclic AMP-dependent protein kinase; FFA, free fatty acids. Adapted from Gregerman RI (1994) Aging and hormone-sensitive lipolysis: reconciling the literature. *Journal of Gerontology: Biological Sciences* 49: B135–B139.

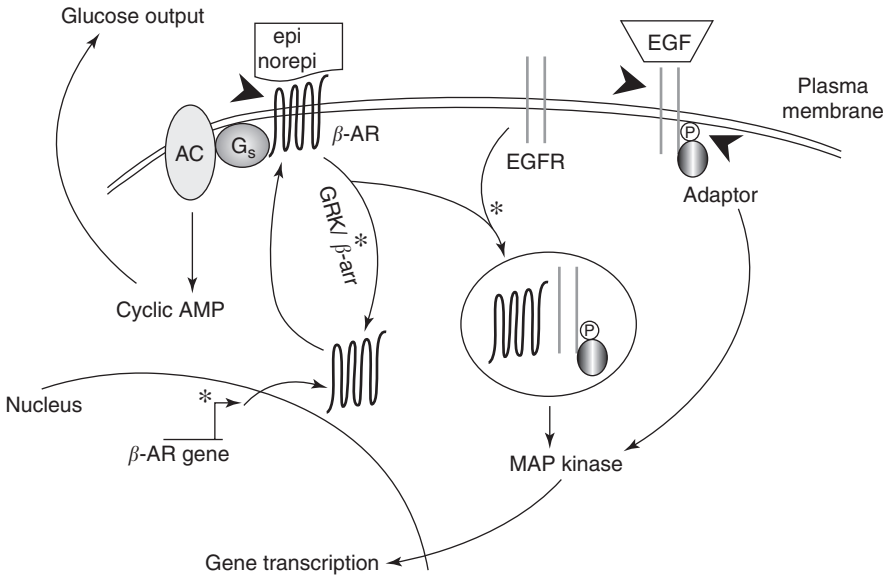

Figure 2 Glycogenolytic and mitogenic signaling pathways in the liver cell. The β-adrenergic responsive glycogenolytic pathway is shown on the left and the epidermal growth factor (EGF) stimulated mitogenic cascade on the right; cross-talk between the two pathways (i.e., β-adrenergic receptor [β-AR]-induced transactivation of the EGF receptor [EGFR]) is pictured in the center of the figure. Arrowheads designate sites at which age-related changes in β-AR and EGFR signaling are known to occur; an asterisk (*) indicates signaling events that *may* be altered during aging (see text). Abbreviations: epi, epinephrine; norepi, norepinephrine; G_s, stimulatory G-protein; AC, adenylyl cyclase; GRK, G-protein-coupled receptor kinase; β-arr, β-arrestin; MAP kinase, mitogen-activated protein kinase.

others (e.g., epididymal fat) (**Figure 1**). The detailed molecular mechanisms determining these age-related changes in rat fat cell lipolysis remain to be clarified. Moreover, the changes of lipolytic signaling found in the aging rat are only variably observed in humans and other species, where in some cases entirely different defects in the lipolytic cascade have been suggested to occur with age. Thus, decreased lipolysis may contribute to accumulation of adiposity during aging in a variety of animal models, albeit by species- and fat depot-specific mechanisms involving diverse changes in the lipolytic signaling cascade.

Glycogenolysis in Liver A second catecholamine signaling pathway characterized by dramatic changes during aging is the β-adrenergic receptor responsive glycogenolytic cascade in rat liver. Early studies limited to young adult male rats indicated that adrenergic responsive glucose output from liver occurs principally by activation of α-adrenergic receptors (i.e., receptors of the α_1 subtype) linked to stimulation of PLC and membrane phosphoinositide turnover. However, subsequent investigations established that postmaturational aging of male rats is associated with progressive increases in β-adrenergic sensitive stimulation of hepatic glycogenolysis via the adenylyl cyclase/cyclic AMP pathway. In liver cells from senescent rats, the glycogenolytic response to β-adrenergic stimuli is greater than that elicited by other stimulatory signals (glucagon and α_1-adrenergic stimuli). The age-related increase in β-adrenergic responsiveness of rat liver can be attributed mainly to an increase in the number of β-adrenergic receptors coupled to adenylyl cyclase in the liver cell membrane (**Figure 2**). Preliminary evidence further indicates that the increased content of membrane β-adrenergic receptors in livers of aging rats is associated with an increase in the expression of the β-adrenergic receptor gene(s). However, it should be remembered that the number of membrane-associated GPCRs, including β-adrenergic receptors, is also normally determined by a complex process in which receptors are desensitized (i.e., uncoupled from G-proteins) and internalized into the cell upon agonist stimulation. Expression of GPCR kinase and β-arrestin, two principal mediators of β-adrenergic receptor internalization, declines with age in rat liver, suggesting that increased numbers of β-adrenergic receptors coupled to classical membrane signaling in livers of aging rats could be caused by defective receptor internalization mechanisms. This possibility (illustrated in **Figure 2**) is of particular interest since sympathetic nervous system activity, as measured by levels of circulating catecholamines, has been shown to increase during aging in both rats and humans. A decline in catecholamine-stimulated functions, which occurs with age in fat and a number of other tissues, may reflect a normal compensatory process of end organ desensitization in response to increased sympathetic tone. Increased β-adrenergic

responsiveness in livers of aging rats might therefore be considered the result of impaired homeostatic processes normally protecting tissues from overstimulation by elevated levels of extracellular signals. At the pathophysiological level, an increase in the content of β-adrenergic receptors coupled to liver glycogenolysis during aging could play a role in the dysregulation of hepatic glucose production that predisposes older people to increasing fasting plasma glucose levels and the development of type 2 diabetes mellitus.

Non-classical Signal Transduction and Aging

Non-classical Signaling Mechanisms

In recent years the field of cellular signal transduction has broadened from considerations of signaling via classical intracellular second messengers to explorations of the mechanisms by which a host of extracellular signals, notably growth factors, promotes the growth, proliferation, differentiation, and survival of cells and tissues. Many growth-promoting signaling proteins, such as epidermal growth factor (EGF), platelet-derived growth factor, nerve growth factor, and fibroblast growth factors, as well as the anabolic hormones insulin and insulin-like growth factor-I (IGF-I), act through a class of cell surface receptors termed receptor tyrosine kinases (RTKs) because of their intrinsic protein-tyrosine kinase activity. Growth factor binding induces RTKs to form dimers and autophosphorylate critical receptor tyrosine residues, which then act as docking sites for adaptor proteins that recruit additional components of a signaling pathway culminating in activation of a family of mitogen-activated protein (MAP) kinases; activated MAP kinases in turn modify cell growth-related processes via phosphorylation of target proteins involved in gene transcription (**Figure 2**). The insulin and IGF-I receptors are tetrameric RTKs that, upon activation by their respective ligands, catalyze the tyrosine phosphorylation of insulin receptor substrate (IRS) proteins and other intracellular intermediates, each functioning to recruit distinct adaptors and downstream signaling molecules resulting in metabolic and mitogenic responses. Interestingly, a number of serine/threonine kinases serving as distal effectors in the insulin signaling pathway also participate in a negative feedback control mechanism that terminates insulin signaling via serine/threonine phosphorylation and inactivation of IRS proteins (**Figure 3**).

In addition to the RTK-mediated signaling cascades, several growth-promoting pathways involving the regulated proteolysis of target proteins play critical roles in cell differentiation and tissue formation during embryogenesis. Of these novel signal transduction systems, signaling through the cell surface Notch receptor appears to be essential for diverse cell fate decisions affecting the development of many tissues and organs. In general, Notch receptors on a given cell are activated by a signaling protein (e.g., Delta) presenting on the surface of a neighboring cell.

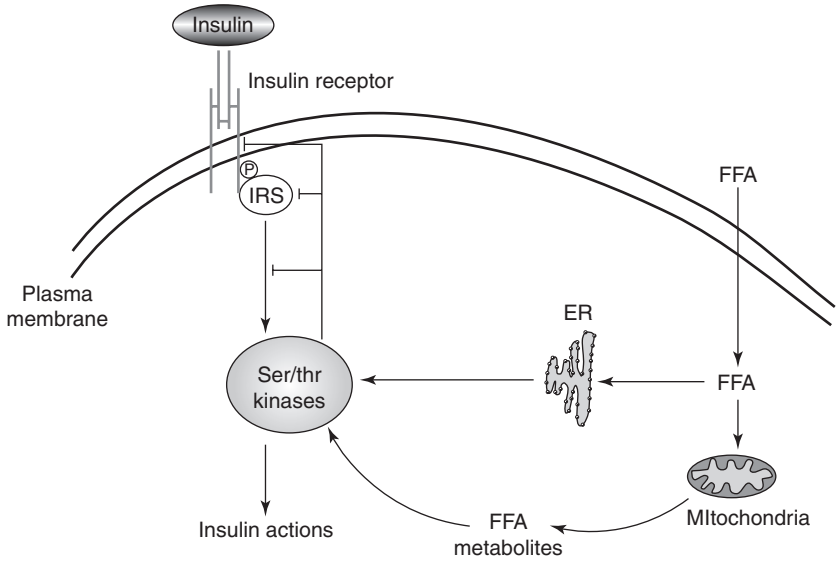

Figure 3 Insulin receptor signaling pathway and potential mechanism underlying insulin resistance. Inducers of insulin resistance (e.g., free fatty acids [FFA]) in type 2 diabetes and possibly during aging may activate mitochondrial and/or endoplasmic reticulum (ER) pathways that block the function of insulin signaling molecules through the actions of serine/threonine (Ser/thr) kinases (see text). IRS, insulin receptor substrate proteins.

Upon binding of the signaling protein, the Notch receptor undergoes proteolytic cleavages that free the cytoplasmic tail of the activated receptor to translocate to the nucleus and activate the CSL family of transcription factors (**Figure 4**). Notch signaling is thought to be involved not only in embryonic development but also in controlling the regenerative capacity of adult skeletal muscle.

Altered Mitogenic and Anabolic Signaling During Aging

The proliferative, or regenerative, potential of many tissues declines with age. A number of studies suggest that impaired regenerative capacity of liver and skeletal muscle in old animals is related to changes in RTK and Notch signaling during aging. EGF and other growth factors acting via RTKs have major effects on liver growth and are thought to play an important role in liver regeneration following liver injury (by drugs, other chemical agents, or viruses) or surgical removal of hepatic tissue. Accordingly, EGF-responsive RTK signaling in rat liver has been studied extensively as a model of reduced cellular proliferative capacity during aging (see **Figure 2**). Liver cells obtained from senescent rats and grown in culture dishes exhibit markedly lower levels of MAP kinase activation by EGF than cells from young adult animals. Levels of EGF receptors do not change with age in cultured liver cells, and the reduction of EGF-induced MAP kinase activation observed in cells from old rats has been linked to an age-dependent decline in autophosphorylation of the activated EGF receptor at a site required for receptor association with an adaptor protein (Shc) that elicits downstream signaling. In contrast to the results using cultured liver cells, a dramatic decline of EGF receptor levels has been demonstrated in whole liver preparations from aging rats. The apparent discrepancy in these findings may be partly explained by observations in early studies suggesting time-dependent loss of activated EGF receptors in liver cells cultured from young rats. Additional investigation will be required to elucidate the mechanisms by which changes in EGF receptor expression and/or function contribute to age-dependent reduction in liver cell proliferation. However, the data currently available in this area of research highlight the fact that studies of complex aging phenomena are subject to a variety of confounding factors, including the experimental conditions utilized.

Recently, investigators have used a mouse model of injury-induced skeletal muscle regeneration to show that impaired proliferative capacity of muscle progenitor cells from old animals is caused by diminished Notch receptor activation, on the basis of inadequate upregulation of the Notch ligand Delta, after injury (**Figure 4**). Notably, in the same series of studies the reduced proliferative potential of both muscle and liver cells in old animals was restored to youthful levels by systemic factors derived from young animals. The identification of these factors, and their role in Notch (or possibly RTK) signaling, may provide fundamental insights into mechanisms of tissue maintenance and regeneration during aging.

In humans the sensitivity of peripheral tissues to the actions of insulin declines during aging,

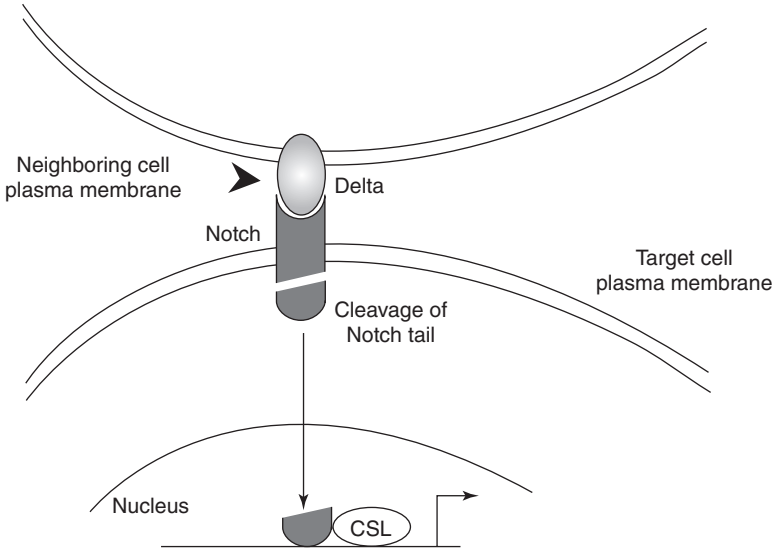

Figure 4 The Notch signaling pathway. Inadequate upregulation of the Notch ligand Delta after injury (arrowhead) appears to play a role in reduced regenerative capacity of skeletal muscle during aging (see text). CSL, a family of transcription factors activating Notch responsive genes.

predisposing the elderly to development of insulin resistance and type 2 diabetes. Considerable research has been focused on the signaling mechanisms underlying insulin resistance associated with aging and diabetes. Animal studies have revealed age-related decreases in early signaling events (e.g., tyrosine phosphorylation of IRS protein) activated by the insulin RTK, although there is no clear consensus relating insulin resistance to any specific defect(s) along the insulin signaling pathway. Accumulating evidence does support a central role for serine/threonine phosphorylation of insulin signaling proteins in the development of insulin resistance. A number of studies, for example, suggest that excess circulating free fatty acids in insulin-resistant states such as obesity and type 2 diabetes suppress insulin signaling by activating serine/threonine kinases – some of which are themselves insulin effectors – that in turn block the function of insulin signaling molecules (e.g., the insulin receptor, IRS proteins, and downstream effectors) through phosphorylation of multiple serine/threonine residues. The cellular pathways underlying fatty acid induction of insulin resistance by serine/threonine kinase activation have been intensively explored, and two non-exclusive proximal mediators have been proposed: (1) fatty acid metabolites accumulating intracellularly on the basis of mitochondrial dysfunction, and (2) signaling events involved in the homeostatic response of the endoplasmic reticulum to protein processing demands imposed by metabolic stressors such as lipid accumulation (**Figure 3**). Evolving research on the interplay of mitochondrial dysfunction, endoplasmic reticulum stress, and control of insulin signaling may identify new pharmacological targets for the treatment or prevention of age-associated diabetes.

The association between insulin resistance and the development of type 2 diabetes, with its adverse consequences, in older people is difficult to reconcile with extensive evidence linking reduced insulin (and/or IGF-I) receptor-related signaling to life span extension in nematodes, flies, and rodents. Data supporting the influence of insulin-like signaling on longevity are derived in large part from mutational analysis, and the extent to which genetic manipulation of metabolic processes can be applied to pathophysiological changes during human aging remains speculative. In this context it should be noted that the metabolic concomitants of insulin resistance, i.e., hyperglycemia and hyperinsulinemia, which are themselves risk factors for diabetic complications and related disorders, are generally not observed in insulin signaling mutants with extended longevity.

Cross-talk between Signaling Pathways During Aging

Numerous instances of cross-talk between signal transduction pathways have been reported. Recent investigations have demonstrated a variety of functional interactions between GPCR and RTK signaling pathways. It has become clear, for example, that a number of GPCRs are coupled not only to G-protein-mediated signaling via classical second messengers, but also to MAP kinase signaling typically responsive to RTKs. In some cases GPCRs induce growth regulatory signals by causing transactivation of RTKs such as the EGF receptor. Interestingly, the process of EGF receptor transactivation by β-adrenergic receptors appears to involve the assembly and internalization of a multireceptor complex containing both the β-adrenergic receptor and the transactivated EGF receptor (**Figure 2**). The mechanisms underlying internalization of the multireceptor complex, including the relationship of this process to GPCR kinase/β-arrestin-mediated internalization of activated β-adrenergic receptors, remain to be clarified.

Little or no information is available on whether interactions between signaling pathways play a role in age-related alterations of tissue responsiveness to extracellular signals. Nonetheless, emerging concepts of cross-talk can provide a useful framework in which to consider at least some changes in signal transduction events known to occur during aging. For example, the increased numbers of adenylyl cyclase coupled β-adrenergic receptors observed in liver cells from old rats may be viewed in the context of cross-talk between the β-adrenergic receptor and EGF receptor signaling pathways. On the basis of evidence that β-adrenergic receptors induce mitogenic signals via internalization in a multireceptor complex with transactivated EGF receptors, and that EGF receptor expression in rat liver declines with age, increasing numbers of cell surface β-adrenergic receptors in livers of aging rats could conceivably reflect a diminished pool of EGF receptors available for co-internalization with β-adrenergic receptors (**Figure 2**). This possibility, though at this point speculative, is likely to be representative of a number of testable hypotheses linking age-related changes in tissue functions to altered cross-talk between cellular signal transduction pathways.

Many of the cellular actions of reactive oxygen species (ROS) appear to reflect mechanisms of cross-talk between the redox state of the cell and cellular signal transduction pathways. Reactive oxygen species generated in mitochondria and other cellular compartments have long been thought to participate

in biochemical reactions causing tissue damage, aging, and age-related diseases. More recently, ROS have also been considered to function as critical regulators of biological processes through complex interactions with classical and non-classical (e.g., receptor tyrosine kinase-mediated) signaling systems. On the one hand, oxidants modulate the activities of a host of signaling pathways presumably through redox modification of reactive cysteine residues on target proteins involved in signal transduction; it should be noted, however, that in many cases the specific signaling targets functionally altered by redox modification are yet to be clarified. Redox regulation of cellular signaling pathways has been linked to control of antioxidant protein expression, insulin signaling, and longevity in a number of animal models. On the other hand, activation of a variety of growth factor receptor and other signaling pathways increases production of ROS, which in turn act as second messengers mediating downstream cellular responses. Mechanisms of bidirectional cross-talk between cellular redox and signaling systems remain incompletely characterized but may well prove to play an essential role in the regulation of gene expression, metabolism, and resistance to stress during aging.

Steroid Hormone Signaling and Aging

Steroid hormones exert diverse actions ranging from regulation of reproductive function to modulation of physiological processes in neural, cardiovascular, immune, musculoskeletal, and gastrointestinal systems. The established model of steroid hormone signaling involves interaction of the steroid molecules with specific intracellular receptors, either cytosolic or nuclear, and a complex of other proteins that together regulate the transcription of certain responsive genes. Whereas the gene regulatory actions of steroid hormones occur over periods of hours to days, it has become clear that some steroid hormone responses occur within a much more rapid time frame (i.e., seconds to minutes). Considerable evidence suggests that these rapid steroid hormone responses are mediated not by transcriptional events, but rather by non-genotropic mechanisms involving second messengers and protein kinases characteristic of plasma membrane receptor signaling pathways. Non-genotropic actions of steroid hormones have been documented in a variety of tissues and are thought to influence the differentiation, physiological function, and survival of numerous cell types. For example, the bone-protective effects of the sex steroid hormone estrogen have been proposed to occur by a non-genotropic mechanism and not by the classical genotropic pathway of steroid hormone action, which – while critical to the control of reproductive tissue functions – may be dispensible for maintenance of bone mass. The genotropic and non-genotropic pathways of estrogen signaling are illustrated in **Figure 5**. In skeletal muscle the anabolic effects of the androgenic sex steroid hormone testosterone reflect hormone actions on both genotropic and non-genotropic pathways. Moreover, in a number of tissues, $1,25(OH)_2$-vitamin D_3, the active form of the

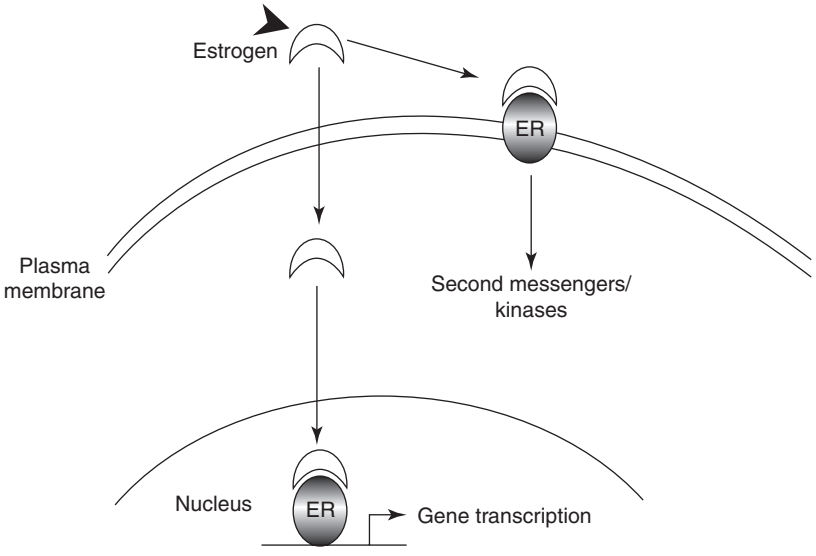

Figure 5 Estrogen signaling pathways. The classical genotropic pathway of estrogen signaling is shown on the left, the non-genotropic pathway on the right (see text). The availability of estrogen (designated by the arrowhead) to bind target cell estrogen receptors (ER) is reduced with age, i.e., at the time of menopause.

secosteroid hormone vitamin D, regulates gene transcription via the classical vitamin D nuclear receptor and also elicits rapid, non-genotropic responses through a plasma membrane-bound vitamin D receptor.

The availability of sex steroid hormones and vitamin D as ligands for target cell receptors is diminished with age in humans. In women, ovarian secretion of estrogen and circulating estrogen levels decline sharply at the time of menopause. In contrast, in men, gonadal sex steroid production and plasma testosterone levels decrease gradually, and to a variable degree, during aging. Low plasma levels of vitamin D are also common in elderly individuals because of limited dietary intake of vitamin D, reduced photosensitive synthesis of vitamin D in the skin during aging, and low exposure to sunlight. Reduced levels of estrogen, testosterone, and vitamin D in older people are all associated with increased risk of age-associated diseases and functional decline. However, steroid hormone 'replacement' may subject aging populations to unexpected, as well as unacceptable, risks. This point was dramatically highlighted by the results of the Women's Health Initiative (WHI), in which large clinical trials of estrogen (and progestin) therapy in postmenopausal women were stopped early because of increased risk of breast cancer and cardiovascular disease in the treatment groups. Several aspects of the WHI study design – specifically, the inclusion of older, overweight women who had no prior hormone therapy and the evaluation of a single estrogen-progestin formulation – have spurred debate over whether the study results are generalizable to other populations and hormone formulations. There is growing awareness that the safe and effective application of therapeutic strategies using natural steroid hormones or synthetic analogs in aging populations will ultimately depend on clinical trials incorporating as yet incomplete insights into the complexity of steroid hormone actions at the molecular level. Fundamental investigations into the tissue specificity of sex steroid actions have already led to the development of selective estrogen and androgen receptor modulators (SERMs and SARMs, respectively), compounds that mimic the beneficial effects of sex steroid hormones on some cell types while antagonizing adverse sex steroid actions on other cell types. Additional research is being carried out to identify new therapeutic agents that retain the favorable, non-genotropic actions of sex steroid hormones on non-reproductive tissues (e.g., prevention of bone loss) without deleterious growth-promoting actions on reproductive tissues (e.g., breast and uterus) via classical genotropic signaling.

Summary

Extracellular stimuli are transmitted into cells and converted into cellular responses by a complex network of signal transduction pathways. Age-related changes at multiple steps along GPCR, RTK, steroid hormone receptor, and other signaling cascades have been implicated in losses of physiological function during aging, as well as in the development of age-associated diseases. Ongoing investigations into the molecular mechanisms of intracellular signaling systems and their involvement in aging and disease will likely lead to the identification of novel pharmacological targets for the treatment or prevention of numerous disorders afflicting older adults.

See also: Andropause; Menopause; Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates; Oxidative Damage.

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Centenarians

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Glossary

Centenarian – People age 100 years and older.

Supercentenarians – People age 110 years and older.

Introduction

Centenarians are rare, though in industrialized nations they are among the fastest-growing segments of the adult population. Such growth suggests that a greater than once anticipated proportion of people have the potential of achieving extreme old age. This proportion, however, is likely still relatively small because rare combinations of genetic, environmental, and perhaps even stochastic events are necessary to become a centenarian. Centenarian studies are making headway in deciphering these factors and combinations of factors, though these efforts are hampered by the likelihood that many combinations lead to such survival and that these combinations vary according to culture, race, and a myriad of circumstances.

Demography

Prevalence of Centenarians

Among industrialized countries, the number of centenarians is increasing at the rate of about 7% per year. At the turn of the twentieth century in the United States, approximately 1 person per 100 000 was a centenarian, and now it is about 1.2 per 10 000. This dramatic increase is the result of public health measures that have allowed people who would have otherwise succumbed to preventable or treatable causes of childhood or premature mortality, such as waterborne and other infectious diseases, to survive to a much older age. Treatment of now readily reversible causes of death among older people is also making a significant impact. In fact, in recent decades, reductions in mortality at the oldest ages have made significant contributions to increased survival and to the increase in the number of centenarians. As a result, today many more people with favorable genetic and environmental traits achieve their maximum life expectancy.

The 2000 US census listed 1400 supercentenarians, people age 110 years and older (about 1 per 200 000), but this is likely a gross exaggeration due to the 50% annual mortality rate in this group and therefore the likely inclusion of deceased persons as alive supercentenarians. According to an Internet-based interest group that monitors and validates claims of age 110 years and older, the number of living supercentenarians in the United States is generally around 75–100 and worldwide, about 300–450.

Validating Age

The oldest verified age claim is that of Jeanne Calment, who, in 1997, died at the age of approximately 122 years. There have been many claims of older ages, but these either have not been verified with appropriate documentation or have been disproved.

Per the recommendations of the National Institute on Aging's Panel on the Characterization of Participants in Studies of Exceptional Survival in Humans, age verification of centenarians begins with obtaining a birth certificate. In the case of more rare and potentially sensationalized ages, such as claims of 110 years old and older, additional proof that indicates age at different times in the person's life and that is consistent with the age claim is necessary. Such forms

of proof include census records, school report card with age, military record, marriage license, employment record, old passport, and parental age on child's birth certificate. The familial reconstitution method is also employed to determine whether parents, grandparents, siblings, and children are appropriate ages in respect to the supercentenarian.

Mortality Rates

James Vaupel and other noted demographers have indicated that the annual mortality rate of centenarians is generally 30%, though this rate understandably and dramatically differs according to the centenarian's health and gender. There has been significant debate among demographers as to what happens to the rate of mortality at extreme old ages. If selective survival occurs at old ages, then one would expect that the more frail individuals die, leaving behind a cohort who is more fit and better able to survive. The result would be a deceleration of mortality rates at these extreme ages. The dying off of individuals prone to diseases that typically peak in incidence at younger ages, thus leaving behind a cohort of select survivors, is known as demographic selection. The observation by some research groups that the incidence of Alzheimer's disease (AD) plateaus at very old ages is consistent with this phenomenon. Ritchie and Kildea performed a meta-analysis of nine epidemiological studies, finding that the rate of increase in dementia prevalence fell off among octogenarians and plateaued at $\sim$40% at age 95. In a longitudinal study of older people living in Cache County, Utah, the incidence of both dementia and AD increased almost exponentially until ages 85–90, but declined after age 93 for men and age 97 for women.

A genetic example of demographic selection is the decreased frequency of the apolipoprotein E epsilon-4 (ApoE ε4) allotype in the oldest old. Individuals who are homozygous for ApoE ε4 have a risk of developing AD that is 2.3–8.0 times greater than the general Caucasian population. The allelic frequency of ApoE ε4 drops off dramatically in the oldest age groups, presumably because of its association with AD and vascular disease. Interestingly, the effect of the ApoE allotype upon AD incidence appears to decrease with age at these very old ages.

These examples not withstanding, the phenomenon of demographic selection occurring at extreme old ages remains controversial. Some argue that because of marked improvements in medical care and public health measures, such selection no longer occurs. In this case, decreased mortality due to improved health care could lead to an increased prevalence of frailty among older survivors because treatment of existing diseases simply postpones death to older ages.

Gender Differences

Save for a very few exceptions, in most populations, the vast majority of centenarians are women; generally, in industrialized nations, they comprise 85% of centenarians. Michel Poulain has reported that in Sardinia, Italy, approximately 50% of centenarians, particularly those living in the mountainous region of the island, are male. But again, generally speaking, female centenarians outnumber males almost nine to one. Despite the fact that many more women achieve exceptional longevity than men, among centenarians the men generally have better functional status. One explanation for this may be that men must be in excellent health to achieve such extreme old age. Women, on the other hand, may be more adept at living with age-associated illnesses, and thus they can achieve exceptional old age even with significant chronic disability, particularly compared to men of similar age.

These observations might indicate a demographic crossover in which women are better off than men at younger old age, and men, although fewer in number, are functionally better off at extreme old age. The underlying reasons why women generally live longer than men and are, at least before menopause, significantly less likely to develop heart disease and stroke are unclear. Estrogen, which might be a powerful antioxidant, has been implicated as an important reason. The recent findings from the Women's Health Study in which some women who were taking estrogen experienced increased rates of cardiovascular illness bring into question the role of estrogen in longevity. Additionally, it has been noted that premenopausal women who undergo hysterectomy but not oophrectomy experience an increased risk for vascular disease that is similar to men. Another possible reason is that women, because of menses, are more iron deficient than men for a 30- to 40-year period. Iron is a crucial catalyst in mitochondrial production of free radicals as a byproduct of metabolism. Perhaps a reduction in available iron leads to less free radical production. For example, iron deficiency has been associated with significant reductions in levels of oxidized low-density lipoprotein (LDL) cholesterol, an essential component of atherosclerotic plaque production. In addition, diets high in heme have been associated with significantly increased risk of heart disease.

Another potential female advantage studied by scientists relates to the fact that males possess one

X chromosome while women have two. Women thus have the prospect for somatic cell selection with advancing age, in which the more fit of two somatic cell populations survives. Stem cell populations that give rise to highly proliferative cell populations (for example, intestinal and skin epithelium, leukocytes) would be particularly prone to such selection. Among the genes on the X chromosome that are of particular interest are those that effect telomere length, in part because those cell populations that resist oxidative stress better might have longer telomeres. Increased telomere length has been associated with both improved proliferative capacity and decreased mortality.

The Centenarian Phenotype

Personality

The Georgia Centenarian Study examined and compared the personality traits of three age groups: centenarians, octogenarians, and sexagenarians. The centenarians scored higher in suspiciousness, radicalism, fatigue, and depression but lower in intelligence, sensitivity, and stress. Preliminary findings from the New England Centenarian Study suggest that female centenarians score low in the personality domain of neuroticism. The subsequent ability to not dwell on things that are stressful could be an important survival trait.

Functional Status

In the Swedish Centenarian Study, 25% lived in their own home, 37% in assisted living, and 38% in nursing homes. In the New England Centenarian Study, the proportions were not too different, with approximately 15% living independently in their own homes, 35% living with family or in assisted living, and 50% living in nursing homes. While the majority of centenarians appear to have functional disability, this disability appears to be compressed toward the end of life. In the New England Centenarian Study's population-based sample, 90% of centenarians were independently functioning at the mean age of 92 years. Most subjects experienced a decline in their cognitive function only in the last 3 to 5 years of their lives.

Despite delaying disability, a large proportion of centenarians still incurs age-related illnesses for many years. In a study of age of onset of age-related illnesses among 424 centenarians (323 males and 101 females), the subjects fit into three morbidity profiles: survivors, delayers, and escapers. Forty-three percent of the centenarians were survivors, or individuals who were diagnosed with age-related illness prior to age 80 (24% of the male and 43% of the female centenarians). Forty-four percent were delayers, individuals who delayed the onset of age-related diseases until at least age 80 (44% of the male and 42% of the female centenarians). Escapers, individuals who attained the 100th year of life without the diagnosis of an age-related disease, accounted for 13% of the centenarians (32% of the male and 15% of the female centenarians). That most centenarians appear to be functionally independent through their early 90s suggests the possibility that survivors and delayers are better able to cope with illnesses and remain functionally independent compared to other individuals who more readily die from those diseases. Thus, in the case of centenarians, it may be more accurate to note a compression of disability rather than morbidity. This is not the case, as would be expected, with illnesses associated with high mortality risks. When examining only the most lethal diseases of the elderly such as heart disease, non-skin cancer, and stroke, 87% of males and 83% of females delayed or escaped these diseases (relatively few centenarians were survivors of such diseases).

Cognitive Function

The population-based Heidelberg Centenarian Study recently reported that both early education and lifelong intellectual activities correlated with better cognitive performance at age 100 years and older. The study reported that about 50% of centenarians demonstrated moderate to severe cognitive impairment and about 25% were found to be cognitively intact. These proportions are approximately the same as the cognitive function studies reported by the Danish (Jeune *et al.*), Swedish (Hagberg *et al.*), Georgia (Poon *et al.*), and New England Centenarian Studies, which indicated that about 70% of centenarians were cognitively impaired and 30% were cognitively intact. Conservatively, with strict criteria for no evidence of cognitive impairment, about 12–15% of centenarians show no evidence of impairment.

Several centenarian studies conduct neuropsychological testing followed by postmortem neuropathological studies, which have led to several interesting observations. A number of cases have been described of centenarians who were cognitively intact near the time of death, yet at autopsy they were found to have no evidence of neuropathology including neurofibrillary tangles and neuritic plaques. These plaques and tangles, which are the pathological hallmarks of AD, were once thought to be inevitable consequences of aging. These cases might be considered examples of disease-free aging,

and they support the notion that for some people, neuropathology is not an inevitable consequence of aging, nor can aging be blamed as the sole reason for the presence of pathology.

Some researchers have observed that the frequencies of various dementia types are different among people who were nonagenarians or older compared with younger cohorts. The Danish Centenarian Study reported that 50% of the dementia cases among centenarians were due to vascular disease. An autopsy series of 13 Japanese centenarians with at most mild cognitive impairment revealed vascular but not AD pathology. It is likely that rare causes of dementia become more common among centenarians because people who are prone to develop AD die at younger ages, leaving survivors to be prone to clinically express other neurodegenerative illnesses such as vascular dementia, Pick's disease, and Lewy body disease.

Familiality of Exceptional Longevity

Heritability Estimates

Twin studies have estimated the heritability of life expectancy to range from 25 to 30%. These twin studies cannot infer the heritability of living to extreme old age because the oldest subjects in these studies were only octogenarians. In contrast, centenarians who live an additional 15–20 years beyond average life expectancy may require more than an advantage in their habits and environment. They may require a genetic advantage that translates into a significant inherited component to exceptional longevity. Some estimates are higher when the phenotype is more specific, as in the case of cognitive function at very old age. Centenarians and their family members may have or lack certain genetic characteristics that result in a significant survival advantage.

Familiality of Exceptional Longevity

Perls *et al.* analyzed the pedigrees of 444 centenarian families in the United States that included 2092 siblings of centenarians. Survival was compared to 1900 birth cohort survival data from the US Social Security Administration. As shown in **Figure 1**, female siblings had death rates at all ages that were about one-half the national level; male siblings had a similar advantage at most ages, though diminished somewhat during adolescence and young adulthood.

The siblings had an average age of death of 76.7 for females and 70.4 for males compared to 58.3 and 51.5 for the general population. Even after accounting for race and education, the net survival advantage of siblings of centenarians was found to be 16–17 years greater than the general population. Relative survival probabilities (RSP) for these siblings increased markedly at older ages, reflecting the cumulative effect of their mortality advantage throughout life (**Table 1**). Compared to the US 1900 birth cohort, male siblings of centenarians were 17 times as likely to attain age 100 themselves, while female siblings were 8.2 times as likely.

The analysis of death rates indicates that the siblings' mortality advantage does not grow as they get older. Rather, their relative probability of survival is a cumulative measure and reflects their lifelong advantage over the general population born about the same time. Such elevated RSP values support the hypothesis that these family members have genetic

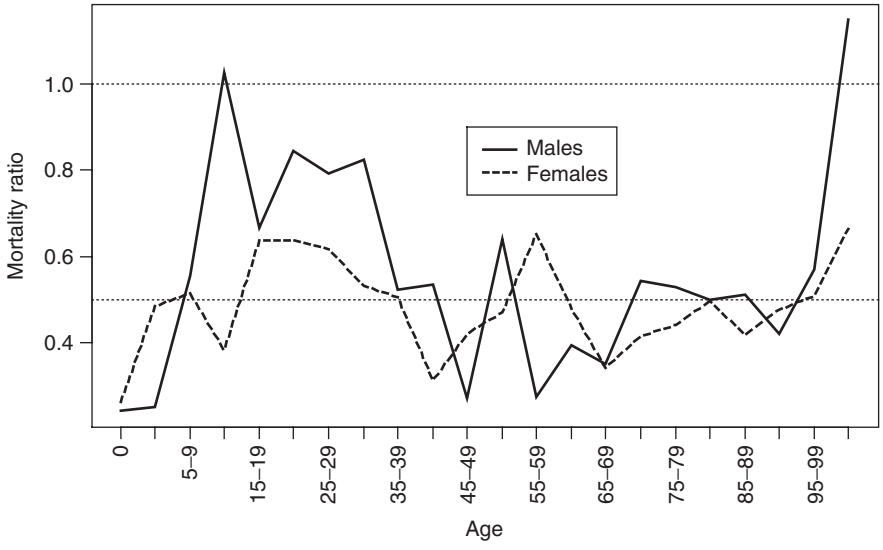

Figure 1 Relative mortality rate of siblings of centenarians compared with their 1900 birth cohort for ages 20 to 100.

Table 1 Relative survival probability (RSP) with 95% confidence intervals (CI) of siblings of centenarians versus US 1900 birth cohort

Age	*Males*			*Females*		
	RSP	*Lower 95% CI*	*Upper 95% CI*	*RSP*	*Lower 95% CI*	*Upper 95% CI*
20	1.00	1.00	1.00	1.00	1.00	1.00
25	1.00	0.99	1.01	1.01	1.00	1.02
60	1.18	1.15	1.21	1.12	1.09	1.14
65	1.29	1.25	1.33	1.16	1.13	1.19
70	1.48	1.42	1.53	1.24	1.21	1.28
75	1.68	1.60	1.77	1.36	1.31	1.41
80	2.03	1.90	2.16	1.54	1.47	1.60
85	2.69	2.47	2.91	1.83	1.73	1.93
90	4.08	3.62	4.54	2.56	2.39	2.74
95	8.35	6.98	9.71	4.15	3.73	4.57
100	17.0	10.8	23.1	8.22	6.55	9.90

variations in common that are important to achieving exceptional longevity. Furthermore, mortality rates of different groups (e.g., gender, race, education, physical activity, socioeconomic status) converge at very old age, and thus such a sustained advantage is unusual. The rarity of sustained mortality differences at older ages in other cases suggests that the mortality advantage enjoyed by siblings of centenarians has some significantly influential etiology, perhaps genetic. The apparent increased probability of exceptional longevity among siblings of long-lived individuals could be inflated by sampling bias. An alternative method, general branching process modeling, has been applied to these data, which can be adjusted to allow for correlations between siblings' life spans, and similar results were obtained. The substantially higher RSP values for men at older ages might reflect the fact that male disease-specific mortality is significantly higher than for females at these older ages, and thus the males experience a greater relative advantage from beneficial genotypes compared with women. Another possibility could be that an even greater, and thus more rare, combination of genetic and environmental factors is required for men to achieve extreme age compared to women. Either possibility could explain why men comprise only 15% of centenarians.

Richard Cutler, in what is now a classic paper in gerontology, proposed that persons who achieve extreme old age do so in part because they have genetic variations that affect the basic mechanisms of aging and that result in a uniform decreased susceptibility to age-associated diseases. Persons who achieve extreme old age probably lack many of the variations (disease genes) that substantially increase risk for premature death by predisposing persons to various fatal diseases, both age-associated and non-age-associated. More controversial is the idea that genetic variations might confer protection against the basic mechanisms of aging or age-related illnesses (the longevity-enabling genes). Centenarians may be rare because a complex set of environmental and genetic variables must coexist for such survival to occur. Based upon studies of centenarian pedigrees, it appears that family members are more likely to have such combinations of factors in common than the general population.

Genes Predisposing to Exceptional Longevity

The discovery of genetic variations that explain even 5–10% of the variation in survival to extreme old age could yield important clues about the cellular and biochemical mechanisms that affect basic mechanisms of aging and susceptibility to age-associated diseases. Until recently, only one genetic variation had been reproducibly associated with exceptional longevity, but even this might vary with ethnicity and other, as-yet-unknown sources of stratification. Schachter and colleagues from the French Centenarian Study noted that the apolipoprotein E $\varepsilon 4$ allele becomes markedly less frequent with advancing age. One of its counterparts, the $\varepsilon 2$ allele, becomes more frequent with advancing age in Caucasians.

Nir Barzilai and colleagues, studying Ashkenazi Jewish centenarians and their families, recently investigated a cardiovascular pathway and gene that is differentiated between centenarians and controls. In this study, controls were spouses of the children of centenarians. Barzilai and colleagues noted that high-density lipoprotein (HDL) and LDL particles were significantly larger among the centenarians and their offspring, and that particle size also differentiated between subjects with and without cardiovascular disease, hypertension, and metabolic syndrome. In a candidate gene approach, the researchers then searched the literature for genes that affect HDL and LDL particle size, and hepatic lipase

and cholesteryl ester transfer protein (CETP) emerged as candidates. Compared with a control group representative of the general population, centenarians were three times as likely to have a specific CETP gene variant (24.8% of centenarians had it vs. 8.6% of controls), and the centenarians' offspring were twice as likely to have it.

Discovering genes that could impart the ability to live to old age while compressing the period of disability toward the end of life should yield important insight into how the aging process increases susceptibility to diseases associated with aging and into how this susceptibility might be modulated. Human longevity-enabling genes are likely to influence aging at its most basic levels, thus affecting a broad spectrum of genetic and cellular pathways synchronously. The centenarian genome should also be an efficient tool for ferreting out disease genes. Comparing single nucleotide polymorphism (SNP) frequencies implicated in disease in centenarians with frequencies in persons with the disease should show clinically relevant polymorphisms. Another approach that researchers are in the early stages of understanding is differential gene expression in models known to slow the aging process, such as caloric restriction. This might prove to be another potent tool for discovering longevity-enabling genes. The hope, of course, is that these gene discoveries will help in identification of drug targets and creation of drugs to allow persons to become more centenarian-like by maximizing the period of their lives spent in good health.

Children of Centenarians

Offspring of centenarians have been found to have lipid profiles associated with lower risk for cardiovascular disease. Other findings include that middle-aged sons of long-lived parents had better systolic pressures, cholesterol levels, and decreased frequencies of the apoE ε4 allele compared to middle-aged sons of shorter-lived parents. Using a questionnaire-based cross-sectional study design, Terry and colleagues assessed the health histories of a nationwide sample of centenarian offspring ($n = 176$) and controls ($n = 166$). The controls consisted of offspring whose parents were born in the same years as the centenarians but at least one of whom died at age 73, the average life expectancy for that birth cohort. The average age at death of the other parent was 77 years, the same as the spouses of the centenarians. Centenarian offspring were found to have a 56% reduced relative prevalence of heart disease (OR 0.44, 95% CI 0.24, 0.80) ($p < 0.01$), a 66% reduced relative prevalence of hypertension (OR 0.34, 95% CI 0.21, 0.55) ($p < 0.01$), and 59% reduced relative prevalence of diabetes (OR 0.41, 95% CI 0.15, 1.12) ($p = 0.01$) in multivariate analyses that controlled for age, gender, years of education, annual income, instrumental activities of daily living (IADL) score, ethnicity, marital status, exercise, smoking, and alcohol use. There were no significant differences in the prevalence of a number of other age-related diseases, including cancer, stroke, dementia, osteoporosis, cataracts, glaucoma, macular degeneration, depression, Parkinson's disease, thyroid disease, and chronic obstructive pulmonary disease. The lack of differences for these diseases may be a function of the sample size or the choice of controls, or it may be that families with exceptional longevity do not have differential susceptibility to these diseases. For the offspring of centenarians who did report hypertension, the age of onset was significantly later when compared to controls. Similar delays were noted for the age of onset of coronary heart disease, diabetes, and stroke.

Conclusion

Centenarian studies are relatively young; formal scientifically rigorous studies began in the 1980s. These studies have grown and new ones have emerged as centenarians have become more common, findings have been reproduced among these culturally diverse studies, and funding studies of the exceptionally old and their families has become a priority. Paralleling this growth has been the development of molecular genetic techniques that are both inexpensive and powerful enough to enable genetic studies of this select cohort that may lead to insights into both environmental and genetic determinants of survival to extreme old age and survival to older age in good health. Centenarians were once thought to be scarce because of a few rare, important determinants. However, it is now suggested that the necessary combination of factors are rare, not the individual factors themselves. An important challenge for centenarian studies is the variability of the combination of factors necessary for different individuals to survive to extreme old age.

See also: Dementia: Alzheimer's; Demography; Genetics; Parkinson's Disease.

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Cholesterol and Cell Plasma Membranes

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Glossary

Arterial Vasospasm – Inappropriate vasoconstriction resulting in the reduction and impairment of blood flow. Vasospastic events result in poor tissue oxygenation and therefore poor tissue function due to impaired blood flow.

Membrane Fluidity – The ease with which lateral mobility of membrane proteins or lipids is permitted along the membrane phospholipid bilayer. Compounds that alter membrane fluidity either increase or decrease lateral mobility of these molecules.

Phenotypic Modulation – In vascular smooth muscle cells, the predominant phenotypic state is the contractile phenotype characterized by robust contractile ability, with reduced protein (matrix) secretion, and little to no replicative ability. In vascular disease, phenotypic modulation occurs in which the smooth muscle cells shift to the synthetic phenotype, which is characterized by marked proliferative activity, augmented protein (matrix) secretion, and reduced contractile ability.

Introduction

The plasma membrane is a lipid bilayer structure separating the intracellular from the extracellular compartments. It provides an important barrier protecting the cell from a variety of molecules present in abundance in the extracellular space. Communication between the cell and its extracellular signals occurs largely through proteins embedded in the bilayer. These integral membrane proteins are held in the bilayer by virtue of a registration of their hydrophobic amino acids with the hydrocarbon core of the membrane bilayer. In this way, the bilayer serves as a two-dimensional solvent system for these signal proteins, which include ion channel proteins, molecular pumps, exchange proteins, and a wide range of cell surface receptors. The ability of these signal proteins to function properly depends on the composition, dynamics, and structure of the membrane solvent features. Changes in bilayer composition have been shown to alter the activity of numerous membrane proteins, many of which play crucial roles in regulating cell function. Age-related

alterations in bilayer lipid composition and dynamics have been described for the plasma membrane in several cell types. Common to most studies is an increase in the cholesterol content of the bilayer. Why this change occurs and the degree to which it disturbs cell function with age needs to be more carefully addressed. This article discusses how cholesterol fits into cell membranes and the molecular interactions it has with the other membrane lipids and how these interactions alter membrane dynamics, structure, and function. In particular, we have focused this discussion on cholesterol's potential involvement in disturbing plasma membranes in cells of the vascular wall and in the central nervous system (CNS), which may contribute to the genesis of cellular defects of two particular diseases that are of special concern in the elderly, atherosclerotic heart disease and Alzheimer's disease (AD).

Background

Membrane Lipid Composition and Physical Characteristics

Many scientists regard the cell plasma membrane merely as the thin black line typically drawn around the cell to delineate the inside of the cell from the outside. Indeed, one of the principal roles of the plasma membrane is to serve as a barrier to keep the cell contents inside and the extracellular contents outside. The membrane bilayer itself is largely resistant to permeation by both charged and most uncharged molecules, as well as a wide variety of extracellular signals. However, the movement of materials and information across this barrier is essential to cell function and is accomplished almost exclusively by membrane proteins that serve transport, diffusion, receptor, and phagocytic processes. Membrane proteins are complex macromolecular assemblies embedded in the membrane lipid bilayer. These transmembrane pathways have been heavily studied and well described. Lost in the interest and activity surrounding the structure–function relations of membrane proteins is the lipid bilayer itself, and the effect that changing the lipid components (i.e., phospholipids and cholesterol) has on the qualitative characteristics of the bilayer. This is a vital issue because the lipid bilayer serves also as a two-dimensional solvent system in which the various membrane proteins are inserted. The proteins are held in the lipid bilayer by virtue of a hydrophobic registration of their lipophilic amino acid residues, with the hydrocarbon core fatty acyl chains. It stands to reason that changes in the composition of the membrane may alter qualitative aspects of the bulk lipid phase and therefore may well have marked effects on functional aspects of the transmembrane proteins. Recent studies described in this article suggest that defects in the bilayer characteristics may have pathogenic roles in important diseases of growing significance to the elderly.

The plasma membrane, like all other membranes in nature is composed of a bilayer of various phospholipids, which include phosphatidylcholine (PC), phosphatidylethanolamine (PE), phosphatidylserine (PS), phosphatidylinositol (PI), phosphatidic acid (PA), and sphingomyelin (SP), as well as various glycolipids. At neutral pH, the phosphorus head group is polar, whereas the fatty acyl chains remain neutral. Thus, phospholipids have amphipathic properties and, as such, they spontaneously assemble into lipid bilayers in aqueous media with the polar head groups oriented toward the aqueous phase and the non-polar fatty acyl chains orienting toward each other, thereby excluding water. In addition, nearly all eukaryotic, but not prokaryotic membranes also require sterols. In mammals, this sterol requirement is exclusively for the 3-hydroxy form of unesterified (free) cholesterol. In mammalian plasma membranes the most abundant phospholipids by mass are PC, PE, PS, and SP, and to a much lesser degree PA and PI. The level of SP correlates well with the amount of cholesterol. SP and cholesterol have been suggested to form non-covalent bonds, and SP levels in membranes appear to be driven, at least in part, by the cholesterol content, to the extent that SP levels may even serve to protect cholesterol content in the plasma membrane. Perhaps the greatest variability in membrane lipids is seen in the cholesterol content. The cholesterol to phospholipid mole ratio (FC:PL) ranges from below 0.1 : 1 (10 mol percent) in most intracellular membranes to over 1 : 1 (100 mol percent) in plasma membranes of Schwann cells and red blood cells (RBCs). At a 0.5 FC/PL mole ratio (50 mol percent) approximately one molecule of cholesterol is present for every two molecules of phospholipid. In most mammalian cell plasma membranes, cholesterol is the single most abundant membrane lipid where the FC/PL mole ratio is approximately 0.3–0.5.

The rationale for phospholipids in the bilayer is straightforward; they are ideally suited to forming the thin, pliable barrier enclosing cells. Furthermore, the intrinsic motion of their fatty acyl chains provides a fluid hydrocarbon core permitting conformational changes in membrane proteins as well as lateral movement of membrane constituents. Thus, without exception, all membranes are composed of phospholipids. As for the rationale for specific classes of phospholipids, the problem becomes more complex, because specific functions for the individual

phospholipid classes need to be identified. In this regard, the phospholipids subserving signaling functions are the easiest to explain. The importance of membrane PI in the IP_3/DAG second messenger pathway is well established, as is membrane SP and its hydrolytic products sphingosine and ceramide in the regulation of cell function, in large part through their effects on protein kinase C (PKC) activity.

However, the role of membrane cholesterol in plasma membranes, unlike phospholipids, is less straightforward. To begin with, although free cholesterol is an absolute requirement in mammalian membranes, it is not a requirement for membranes of lower life forms. Indeed, prokaryotes have no sterols in their membranes. So why eukaryotes need a membrane sterol, and why mammals in particular choose cholesterol for their membrane is odd, and perhaps unfortunate because cholesterol's requirement for membrane and hormone synthesis is countered by its potential lethality in the bloodstream. Free cholesterol is highly insoluble in aqueous media so it readily partitions into phospholipid bilayers. In fact, this is its exclusive intracellular location. In mammals 3-hydroxycholesterol is the only membrane cholesterol species. The presence of the 3-hydroxy group confers a specific orientation of the molecule in the bilayer such that the polar hydroxyl group orients this end of the sterol ring near the surface of the bilayer in the polar phosphorus-head group region. The hydrophobic ring structure partitions into the fatty acyl chain region of the phospholipid leaflet where it occupies a position spanning approximately 6 to 15 Å out from the center of the bilayer. The sterol ring is a planar, conformationally inflexible ring structure, and in this position in the bilayer it can greatly hinder the intrinsic motion of the fatty acyl chains, thereby ordering the bilayer and reducing membrane fluidity in native membranes. In addition, kinks in the phospholipid fatty acyl chains are thought to create transient free volume elements or open space regions in the membrane bilayer during acyl chain motion. These free volume elements likely provide pathways for the movement of small molecules like glucose that can diffuse across lipid bilayers, a process that is reduced by increasing the cholesterol content of the bilayer. They may also provide the space or breathing room for protein conformational changes necessary for membrane proteins to mediate transport of materials and/or information from one side of the bilayer to the other. The fractional free volume is therefore reduced by cholesterol in proportion to its concentration in the membrane. In this way, altering membrane cholesterol levels may well hinder activity of some membrane proteins. The functional significance of cholesterol in membranes likely relates, in part, to its ability to set the level of fluidity and fractional free volume. More recently, membrane cholesterol content has also been shown to greatly affect membrane bilayer width, a parameter function with considerable potential consequences to the activity of various membrane proteins. As described below, there is a direct, linear, and highly significant relationship between membrane cholesterol and bilayer thickness. This structural effect of cholesterol on membranes is another interesting and important function of this sterol, and one that is likely integrated into the membrane cholesterol regulatory scheme.

The asymmetrical distribution of cholesterol in cells is another intriguing aspect of this sterol. Several lines of evidence suggest that the greatest fraction of cell cholesterol is located in the plasma membrane where the FC/PL mole ratio is usually around 0.5. This is much higher than is thought to exist in mitochondrial, lysosomal, Golgi, endoplasmic reticulum (ER), or nuclear membranes. In fact, free cholesterol is often used as a marker for the plasma membrane. Using the cholesterol oxidase assay in a fibroblast cell line, Evonne Lange has estimated that over 90% of the cell's cholesterol is in the plasma membrane. However, the cholesterol oxidase technique is not without its shortcomings, and this value may be an overestimate. Nonetheless, current wisdom holds that the plasma membrane is highly enriched with cholesterol relative to the subcellular membranes. Why this asymmetry exists is not clear, but it may be necessary to provide a suitable barrier function of the plasma membrane lipid bilayer. Because cholesterol reduces the fractional free volume of the bilayer, it limits bilayer permeability to small molecules that would otherwise diffuse across it more readily. Lastly, because cholesterol impacts on bilayer structure, it may also provide suitable structural conditions for proper function of the membrane proteins.

Regulation of Membrane Cholesterol

Generally, lipid–protein interactions are regarded as either direct (i.e., a certain lipid species may be required for a protein to function properly) or indirect (as through membrane microviscosity). Both of these interactions have been demonstrated for membrane cholesterol. For any given cell line, the plasma membrane seems to be relatively fixed with regard to its phospholipid profile and cholesterol composition, but significant differences between cell lines are common. Thus, each cell line seems to know what its plasma membrane phospholipid and cholesterol composition ought to be and strives to maintain its

unique profile. This suggests that the plasma membrane lipid composition is carefully regulated, presumably at the genomic level. Although this all makes good sense, it is difficult to understand this regulation because membranes are self-assembled structures. Nonetheless, phospholipid profiles can be generated, at least in part, through their differential synthesis and assembly into Golgi membranes destined for the plasma membrane. Further cell-specific refinement of the phospholipid profile is accomplished through the synthesis and regulation of various phospholipid-active enzymes, such as the various cellular phospholipases and flipases. However, these pathways do not explain the regulation of cholesterol content of the plasma membrane. Nearly all cells have the capacity to synthesize cholesterol, a pathway that is largely held in check in mammals by an abundance of cholesterol that comes to the cell from the outside, primarily by lipoproteins. Cholesterol appears to gain access to the membrane bilayer primarily by aqueous diffusion, as this route has been established for the movement of cholesterol between phospholipid surfaces, between low-density lipoproteins (LDL) and smooth muscle plasma membranes, and between subcellular membranes. Membrane cholesterol levels are determined by the relative rates of cholesterol absorption into and desorption out of the bilayer. In the steady state, these rates must be equal. In non-steroidogenic and non-proliferating cells, the supply of this sterol to cells is almost exclusively through plasma LDL, the level of which is greatly affected by dietary and hepatic factors. Under normal conditions, removal of cholesterol from the membrane is accomplished by high-density lipoprotein (HDL) from the outside (reverse cholesterol transport), a largely unregulated process for cholesterol removal from peripheral cells. Thus, because the extracellular routes for cholesterol to the plasma membrane are unregulated, membrane cholesterol is likely regulated from inside the cell, presumably by the cholesterol esterification/de-esterification pathways (ACAT and CEH). Because these enzymes have only recently been purified through cloning techniques, this regulatory pathway has yet to be defined, and our understanding of the details of how cellular-free cholesterol levels, and therefore also membrane cholesterol, are controlled is meager at best. It is clear, however, that cells are good at regulating their membrane cholesterol levels. For example, in arterial smooth muscle cells (SMCs) in culture, enrichment of the cells with cholesterol using cholesterol donor liposomes increases the membrane FC/PL mole ratio. When the cholesterol-enriched SMCs are then left in culture without the liposomes, the SMC membrane cholesterol content gradually returns back to control levels over 4–5 days. This return is accompanied by an increase in cell cholesteryl esters, consistent with regulation by the ACAT/CEH pathway.

Isolating Plasma Membranes for Study

In any discussion of plasma membrane composition or characteristics, a comment on membrane isolation is essential because the limitations of the technique are important to understand. A major technical problem impeding our understanding of the composition, dynamics, and structure of the membrane lipid bilayer has been the extreme difficulty in isolating and studying it in pure form. On the one hand, membrane function can most easily be studied using transport techniques (i.e., measuring the movement of ions and molecules into [influx] and out of [efflux] cells). However, this type of transport is mediated mostly by large, complex, amphipathic proteins, and the degree to which the lipid characteristics of the bilayer contribute to this process is hard to delineate. For this, the plasma membrane must be isolated, and herein lies the problem. The standard and by far most common approach to isolate plasma membranes is to fractionate the cells osmotically or mechanically, followed by differential ultracentrifugation. This can be applied to intact tissue, dispersed cells, and cells in culture. Differential ultracentrifugation yields a membrane fraction (i.e., microsomes) containing varying degrees of purity relative to internal subcellular membranes. Unfortunately, pure plasma membranes are impossible to obtain. Contaminating the microsomal membrane fraction are the other light membranes such as Golgi and ER membranes. Even with further fractionation, such as gradient ultracentrifugation of the microsomal membrane preparation, contamination is reduced, but not eliminated. Compounding purification by ultracentrifugation, yield is disproportionately reduced as purity is increased. Lastly, even with extreme care and refined procedures, lipid exchange between membrane fractions during the sample preparation cannot be avoided. Hence, what was pure plasma membrane to the cell becomes something less in the test tube. Notwithstanding these difficulties, relatively pure plasma membranes can be prepared and studied, so long as one appreciates that the ideal pure plasma membrane is only a theoretical endpoint. For this reason, the differential distribution of membrane markers is important to demonstrate in any membrane preparation, without which it is impossible to estimate the degree of purification.

Alterations in Membrane Cholesterol: Compensatory Versus Pathological

Compensatory Alterations

Because changes in membrane cholesterol, in either direction, disturb lipid bilayer dynamics and structure, it seems reasonable to suspect that this would also alter membrane and cell function. There is abundant evidence supporting this notion using *in vitro* systems. For example, in cultured arterial SMCs in early passage, increasing membrane cholesterol content, as a single, isolated and independent variable, increases passive membrane permeability to calcium as illustrated in **Figure 1**. In these studies, alterations in membrane cholesterol were accomplished by incubating SMC monolayers overnight with either cholesterol donor liposomes (FC: PL $\approx 2:1$) or cholesterol acceptor liposomes (FC:PL $= 0:1$). It is clear that when membrane cholesterol increased above control levels, calcium permeability increased, and when membrane cholesterol levels were decreased below control levels, calcium permeability also decreased. Moreover, following the shift from either high or low cholesterol levels, if the SMCs were placed in cholesterol-neutral medium, the membrane cholesterol alteration reversed back to control levels, as did passive calcium permeability. Because calcium is an important cell second messenger, these studies suggest that changes in membrane cholesterol levels are likely to have marked influences on cell function.

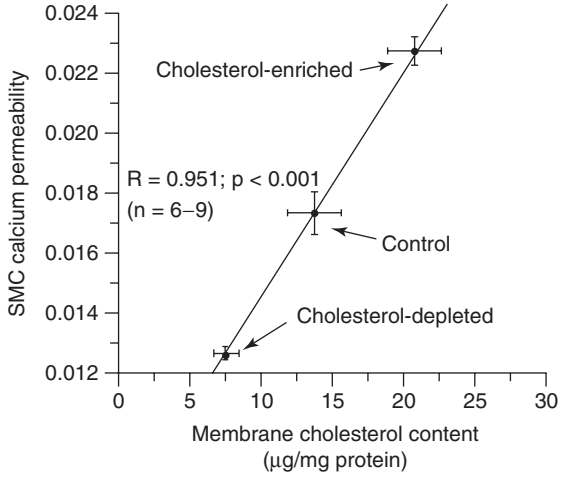

Figure 1 Effects of altering membrane cholesterol content on the permeability of the cell to calcium. SMC, smooth muscle cell. A marked decrease in calcium permeability is seen with decreases in membrane cholesterol content, whereas a marked increase in membrane calcium permeability is seen with increases in membrane cholesterol content. Membrane cholesterol content is expressed as the mass of cell-free cholesterol per milligram cell protein.

However, *in vivo*, it is not always apparent whether changes in membrane cholesterol are pathological or compensatory. This is particularly true in studies of age-related alterations. Several studies have demonstrated an increase in cholesterol content with age including neuronal, cardiac, and arterial SMCs. **Figure 2A** illustrates an increase in the FC/PL mole ratio with age in SMC membranes isolated from the aorta of Fisher 344 rats. In these studies, cholesterol enrichment was evident only in the senescent period. **Figure 2B** illustrates marked alterations in membrane phospholipids from the same samples. These changes in membrane lipid composition with age are accompanied by changes in K^+ permeability as illustrated in **Figure 2C**, which demonstrates an age-dependent suppression of K^+ efflux through the Ca-dependent K^+ channel with adrenergic stimulation. As with free cholesterol (FC) content, this is particularly evident in the senescent period. Studies like this are therefore consistent with the conclusion that, at least in arterial smooth muscle, aging is associated with a remodeling of the membrane bilayer. Remodeling of this type (i.e., an increase in cholesterol and ridigizing phospholipids [PC]) would be expected to reduce membrane fluidity, and this has been reported in other cell lines by other investigators. However, these changes in smooth muscle membrane lipid composition, lipid dynamics, and membrane function with age are apparently not associated with equivalent changes in tissue function, because contractile properties, passive stiffness, collagen, and elastin synthesis do not appear to be altered with age, at least in this animal model of aging (Fisher 344 rat). We conclude from this that these age-related changes in membrane lipids were either unrelated to cell function, or that they constituted a physiologic compensatory response to aging so as to protect cell and tissue function.

Changes in membrane lipid composition in neuronal cells as a function of age have been previously reported. Specifically, an increase in cholesterol content (i.e., increased FC/PL mole ratio) has been reported for cortical gray matter, whole brain lipid extracts, as well as in platelets and lymphocytes derived from aged human subjects. In neuronal microsomes, *in vitro* manipulation of membrane cholesterol content alters the binding activity of various neurotransmitters to their respective receptors. In addition, changes in synaptic membrane signal transduction have also been observed that correlate with increases in membrane cholesterol content. In many cases, the effect of cholesterol enrichment may be reversed with membrane-fluidizing agents, including S-adenosylmethionine, but the degree to which fluidizing the membrane alters membrane structural

parameters has not been determined. Metabolic alterations leading to changes in membrane cholesterol can only be speculated. LDL receptors are expressed on neural cells. Apoprotein E, one of the LDL receptor's two ligands, is synthesized in astrocytes. This suggests that LDL, the cholesterol-rich lipoprotein in humans, may have an important role in cholesterol metabolism in the CNS. Although this relationship has been clearly established for peripheral cells, the relationship between plasma cholesterol levels and neuronal membrane cholesterol content has yet to be defined. However, age-related changes in cell and membrane cholesterol content have been described in several neuronal tissues, but the degree to which these alterations in membrane cholesterol content reflect compensatory or pathological processes is not clear.

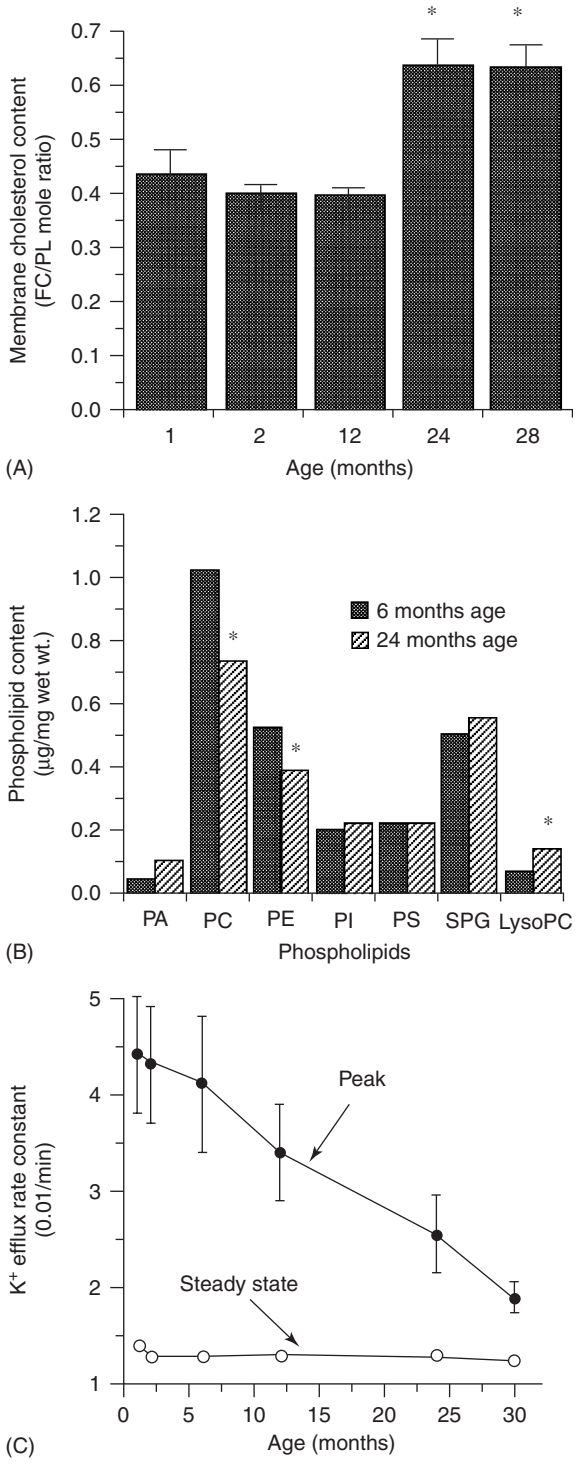

Figure 2 (A) Age-dependent alterations in membrane cholesterol content in aortic smooth muscle isolated from Fisher 344 rats at various ages. There is nearly a 50% increase in membrane cholesterol content in the senescent period (24–30 months). Between 9 and 18 animals were studied in each age group. (B) Alterations in membrane phospholipids with age in aortic smooth muscle isolated from Fisher 344 rats. For simplicity, only the 6- and 24-month ages are illustrated. Note significant reductions in phosphatidylcholine (PC) and phosphatidylethanolamine (PE) at 24 months while lysophosphatidyl-choline (lysoPC) is increased. The significance of these alterations is not clear in that tissue functional parameters (vasoconstriction and stiffness) were not altered at these ages. Between 9 and 18 animals were studied. PA, phosphatidic acid; PI, phosphatidylinositol; PS, phosphatidylserine; SPG, sphigomyelino). (C) Age-dependent decrease in K^+ efflux induced by activation with norepinephrine (NE, 1 μM) in rings of aortic smooth muscle obtained from Fisher 344 rats at various ages. Solid circles indicate peak activation K^+ efflux values and open circles indicate steady-state K^+ efflux values. Currents mediated by K^+ efflux tend to stabilize the cell membrane. In arterial smooth muscle, activation of this current by NE prevents membrane depolarization, which would be expected to limit vasoconstriction. Whether this decrease in K^+ efflux over age alters vasoconstriction to NE is unlikely as force generation to NE was unaffected by age in these experiments. For this reason, these changes are likely compensatory rather than pathological.

Disease-Related Alterations in the Elderly: Alzheimer's Disease

Unlike the alterations in membrane composition and function noted above, which occurred in the absence of alterations in tissue function, notable alterations in certain neuronal membrane bilayers have been seen in conditions clearly associated with functional deficits. A good example of such a potential pathogenic alteration is seen in Alzheimer's disease (AD), a major neurological disorder in the elderly. AD is a neurodegenerative disorder associated with aging that is characterized by progressive loss of higher intellectual function in the absence of focal neurologic defects. A characteristic neuropathological lesion in the cerebral cortex of patients with AD is the neuritic plaque composed primarily of a 42-amino-acid peptide, referred to as beta amyloid (βA4). The number of neuritic plaques generally correlates with the degree of dementia in AD. The

mechanism underlying the elevated formation of βA4 is not well understood, however (*see* Dementia).

The βA4 peptide is derived from a large, membrane-bound amyloid precursor protein (APP) that is broadly expressed throughout the cerebral cortex. Proteolysis experiments indicate that the cleavage site on APP that releases the βA4 peptide fragment is the carboxy terminal end of βA4. The site is normally embedded in the membrane bilayer, and hence, formation of the βA4 peptide fragment is prevented. It is possible that the basis for abnormal APP cleavage that leads to βA4 formation may be related to fundamental changes in membrane lipid composition and structure that could lead to exposure of the βA4 cleavage site.

Alterations in the lipid composition of neuronal membranes in AD has been characterized by various methods, including ^{31}P nuclear magnetic resonance (MRI) thin layer chromatography, and elemental analysis. These studies have demonstrated marked changes in phospholipid composition, including certain metabolites of phospholipid degradation. In addition, biochemical analyses indicate that the cholesterol content of neuronal membranes isolated from an affected cerebral cortical region of AD brain tissue is significantly lower than in corresponding age-matched control and Parkinson's disease samples. The effect of changes in neuronal lipid composition on the structure of plasma membrane lipid bilayers has been directly determined with the use of small angle X-ray diffraction. The results of this analysis showed a reproducible reduction in the overall width of reconstituted AD membrane lipid bilayers relative to age-matched controls. We suggest that this thinning of the membrane bilayer may increase the probability for proteolytic cleavage and release of the βA4 fragment from APP. Interestingly, there was no evidence for changes in lipid composition or structure in neuronal membranes reconstituted from unaffected regions of the AD brain (i.e., cerebellum) relative to control subjects. Furthermore, this reduction in membrane lipid bilayer width could be reversed by adding cholesterol back to the AD samples. Thus, abnormal cleavage of APP may be attributed to basic changes in the architecture of the neuronal plasma membrane bilayer secondary to reduced cholesterol content. Why membrane cholesterol content in these membranes is decreased is not clear and constitutes a clear direction for future studies. Of note is the recent discovery of the expression of an apo E isoform (E_4) in AD patients, the presence of which appears to predict risk and severity for developing AD. However, any link between dysregulation of apo E and altered cortical membrane cholesterol and structure in these subjects has yet to be demonstrated.

Disease-Related Alterations in the Elderly: Atherosclerosis

Another disorder of increasing prevalence with age is heart disease and stroke. Here a link between defects in membrane cholesterol and cell function may also be important. In industrialized cultures, nearly one-half of all causes of death can be attributed to arterial wall disease in which the gradual buildup of fatty lesions and plaque on the luminal surface of large arteries encroaches on organ blood flow. This very gradual, silent process converts in a matter of moments to the acute life-threatening crisis of myocardial infarction or stroke when plaque rupture occurs triggering thrombotic occlusion and ischemia of downstream tissues (*see* Atherosclerosis).

Although cardiovascular mortality is clearly linked with elevated serum cholesterol levels, the cellular basis for atherogenesis is very poorly understood. Moreover, just how molecular cholesterol *per se* fits into the pathophysiology of atherosclerosis has been a total mystery. However, there is a growing belief that serum hypercholesterolemia and/or defects of lipoprotein metabolism lead to the abnormal retention of LDL in the arterial wall. Once there in concentrations greater than can be cleared effectively by the monocyte–macrophage pathway, several biological events likely occur that lead to plaque development and the eventual demise of the arterial lumen and organ blood flow. Recent studies shed new light on the cellular basis of atherogenesis and clearly point to defects in membrane cholesterol levels as a potentially important element in the early pathogenic alterations of arterial wall cells in this disease. Studies from our laboratories have shown that enrichment of arterial SMC plasma membranes with cholesterol augments vasoconstrictor activity by increasing calcium permeability and cytosolic calcium levels. Although these studies were performed *in vitro*, more recent studies have demonstrated very similar findings in rabbits fed a cholesterol-enriched diet for up to 10 weeks. In these studies, atherosclerotic lesions developed in the aorta, and aortic wall segments were isolated and studied for their vasoconstrictor activity and calcium permeability. Again, basal and stimulated calcium permeability and cytosolic calcium levels were elevated. This change in calcium handling was accompanied by an increase in vasoconstrictor activity to adrenergic stimulation and stimulation with serotonin. We concluded from these studies that the augmented vasoconstrictor activity was caused by the elevated cell calcium levels in SMCs, and this defect may explain the common occurrence of vasospastic syndromes in atherosclerotic vessels. Based on our previous studies, we speculated

the increase in SMC calcium permeability was secondary to an increase in SMC plasma membrane cholesterol content. This notion was strongly supported in studies in SMCs freshly dispersed from the aorta of cholesterol-fed animals. We found that the cholesterol content of the SMC plasma membrane increased as a function of time on a high-cholesterol diet. Using small angle X-ray diffraction analysis, we also found that the membrane bilayer width increased over the cholesterol feeding period, and this increase in membrane width correlated very highly with membrane cholesterol content, as illustrated in **Figure 3**. This relationship between membrane width and membrane cholesterol content was preserved regardless of cell origin (i.e., cultured vs. freshly dispersed SMCs) or method of enrichment with cholesterol (*in vitro* with liposomes or *in vivo* by cholesterol feeding to animals). Moreover, this increase in bilayer width and cholesterol content was apparent prior to the appearance of visible lesions, suggesting that the enrichment of SMC plasma membranes in dietary atherosclerosis is an early event in the genesis of atherosclerotic lesions. That excess membrane cholesterol is causally linked to these changes in SMCs during atherogenesis is strongly inferred by our recent observation that they are all reversed back to normal levels following reversal of membrane cholesterol content by incubation of the cells overnight with the human cholesterol acceptor lipoprotein HDL.

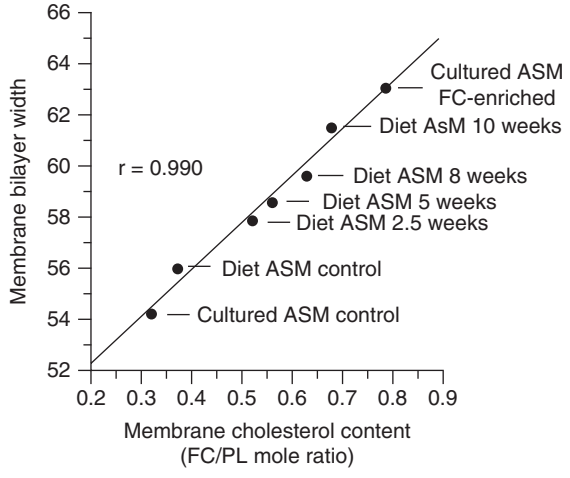

Figure 3 The effects of membrane cholesterol enrichment on membrane bilayer width as determined using small angle X-ray diffraction. Membranes were freshly isolated from smooth muscle cells (SMC) dispersed from the rabbit aorta. Note that the increase in membrane cholesterol tracked with the duration of cholesterol feeding as well as with membrane width. This correlation of membrane width with membrane cholesterol content was preserved for SMC enriched in culture with cholesterol donor liposomes as well as in SMC freshly isolated from rabbits fed cholesterol for up to 10 weeks.

In comparing the membrane and cell alterations that result from acute cholesterol enrichment of SMCs in culture with membrane and cell alterations that are seen in SMCs isolated from atherosclerotic aorta, we have concluded that the phenotypic alterations in SMCs that are seen in atherogenesis may actually be induced by enrichment of the SMC plasma membrane. These membrane alterations common to acute cholesterol enrichment *in vitro* and chronic cholesterol feeding (*in vivo*) include elevated membrane cholesterol levels, decreased membrane fluidity, increased membrane width, increased membrane calcium permeability, decreased membrane Na^+/K^+ ATPase activity, and an increase in unstimulated and stimulated cytosolic calcium levels. The cellular phenotypic alterations induced by cholesterol *in vitro* that are common to *in vivo* hypercholesterolemia include increased cytosolic calcium levels, increased contractile function, increased proliferation rate, and increased mitogen secretion. The ability of human HDL to reverse all these membrane and cell functional alterations strongly supports the hypothesis that they are all driven by enrichment of the SMC plasma membrane with cholesterol. It is clear that excess membrane cholesterol may have broad cellular consequences owing to its ability to induce phenotypic modulation in SMCs. Whether it is also responsible for the increased synthesis of extracellular matrix typical to atherosclerotic lesions is currently under investigation.

In summary, these findings have led us to speculate that enrichment of the SMC plasma membrane with cholesterol contributes to the changes in SMC metabolic activity seen in atherogenesis. Thus, the development of excess membrane cholesterol in SMC secondary to retention of LDL in the arterial wall may play a pivotal and early role in the genesis of the cellular defects responsible for this important human disease.

Summary

It has been known for some time that cholesterol is a major lipid constituent of cell plasma membranes. Although its role there has been regarded largely along the lines of setting membrane fluidity, it is becoming increasingly clear that it also has important membrane structural effects. Changes in membrane cholesterol composition have been demonstrated to induce significant alterations in the activity of various membrane proteins, and therefore also in cell function, including alterations in the phenotypic state, at least in SMC. However, in age-related alterations, it is not clear whether the alterations in membrane cholesterol reflect compensatory alterations or

pathologic alterations. In the case of AD and atherosclerotic vessel disease, two major disorders of prevalence in the elderly, cholesterol may well be playing a pathogenic role. However, in other situations, changes in membrane cholesterol appear to be part of a compensatory response to aging designed to actually protect or preserve cell and tissue function. Thus, molecular cholesterol appears to play a vital role in regulating the healthful activities of cells by its ability to modulate characteristics of plasma membrane that permit optimum performance to the wide array of membrane proteins on the cell surface.

Acknowledgments

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See also: Atherosclerosis; Dementia.

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Cognitive-Behavioral Interventions

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Glossary

Cognitive Triad – Pattern of dysfunctional thinking characteristic of depressed persons in which they hold negative beliefs about the self, experiences, and the future.

Dysfunctional Thought Record – A cognitive-behavioral technique that is used to help individuals identify and monitor cognitive distortions.

Schema – Long-standing underlying assumptions or systems of belief from which the basic cognitive distortions and automatic thoughts emerge.

Introduction

Cognitive-behavioral therapy (CBT) is an approach to treatment of psychological problems that emphasizes the relationship among cognitive processes (thoughts or beliefs), emotions, and behavior. The assumption is that what one believes about an event or experience impacts how one feels and behaves in that situation. Similarly, the activities or behaviors that one engages in will affect mood and thoughts.

Thus, a depressed person is often trapped in a downward spiral of negative thoughts that lead to depressed feelings and disengagement from meaningful and pleasant activities. The approach to treatment assumes that changes in thoughts and behaviors will result in changes in mood. The process of treatment is active and directive, with the therapist and patient working collaboratively to identify and change negative or dysfunctional thoughts and increase participation in meaningful activities. The goal of CBT is to teach the skills needed to change the dysfunctional thinking and behaviors that contribute to negative mood. Thus, CBT emphasizes the teaching of coping skills for dealing with problems rather than 'curing' the problem. The expected consequence of teaching these skills is an increase in patients' sense of self-efficacy, competency, and coping abilities. These skills equip them to deal not only with present problems, but also with future problems. The leading figures in the development of general cognitive therapy approaches to treatment of mood disorders are Albert Ellis, Donald Meichenbaum, and Aaron Beck.

Theoretical Assumptions of Cognitive-Behavioral Therapy

Causes of Problems

CBT assumes that negative emotions are linked to an individual's capacity to distort reality in dysfunctional ways, which often results in withdrawal from meaningful activities. The combination of these processes creates a downward depressive spiral that limits the individual's capacity to respond to life challenges in a functional way. Thus, while everyone experiences stressful life events over the course of a lifetime, it is the individual's subjective evaluation and behavioral response to that evaluation that determine whether they experience psychological distress. The interaction between the experience of a stressful event and the individual's perception and response to that event predicts outcome.

Beck's cognitive model identifies three specific factors that disrupt an individual's capacity to perceive and respond to experiences in a functional way. The first is known as the 'negative or cognitive triad,' an interactive set of negative or distorted beliefs about the self, experiences, and the future. Depressed persons often believe themselves to be unworthy, deficient, or unlovable and interpret negative life events as their fault or as a result of their own inadequacy. Thus, the person who does not get an expected promotion at work might attribute this to the belief 'I am mediocre,' rather than considering alternative explanations (e.g., 'The person who got the promotion had more seniority'). In the same way, beliefs about life events and the future will filter the way an individual interprets his or her experience.

The second factor in Beck's model is maladaptive 'schema.' Schemas are stable organizational patterns of thought that form the basic framework for classifying and evaluating experience. These schemas reflect a kind of world view represented by a set of underlying beliefs about self and others. Often these beliefs, while automatic, are implicit and out of the awareness of the person. Maladaptive schemas impair the individual's ability to objectively evaluate interactions and events, foster a persistent negative response bias, and frequently result in negative affective and behavioral symptoms. For example, following the death of a spouse, the person who holds the schema 'I must have someone to take care of me,' would be likely to endorse such statements as 'I will never be safe (loved, cared for) again.' This schema pushes the individual into an unrealistic appraisal of the situation and to a negative appraisal of self, experience, and the future.

The third factor in Beck's model is that maladaptive schemas lead to errors in information processing and logical thinking. In particular, identifiable patterns in cognitive errors are common and include (1) selective attention (focusing on some details while ignoring other relevant facts of the situation), (2) overgeneralization (assuming that the outcome of one incident will occur in all situations), (3) arbitrary inference (drawing a conclusion in the absence of evidence), (4) magnification or minimization (distorting the importance or significance of a single event), (5) personalization (assuming automatically that external events relate to oneself), (6) 'all-or-none' thinking (categorizing continuous experiences as dichotomous extremes, such as good or bad, loved or hated).

The consequence of these dysfunctional cognitive processes is often a behavioral response that removes the individual from active engagement in enjoyable or meaningful activities. The loss of enjoyable activity contributes to the downward spiral of depression and makes it difficult for the individual to recover from a challenging or stressful life event.

Goals and Strategies of CBT

The goal of CBT is to address the dysfunctional thoughts and beliefs that are causing distress to the older adult and to encourage more adaptive cognitive and behavioral responses. The cognitive component of CBT seeks to identify the dysfunctional thoughts and beliefs that lead to errors in cognitive processing and to teach individuals the skills that permit a more

balanced and accurate view of their situation. The behavioral component emphasizes the relationship between activity and mood and encourages increased participation in pleasant activities, decreased participation in aversive activities, and improved problem-solving and social skills.

To address the cognitive distortions, the process of therapy includes the following components:

1. Identifying the specific negative thoughts associated with a specific event.
2. Establishing the relationship between negative thoughts and feelings associated with that event.
3. Learning specific CB techniques for challenging negative or dysfunctional thinking.
4. Developing more adaptive interpretations and responses to specific situations.
5. Identifying and altering general maladaptive schemas that foster development of depression and/or anxiety.

The concerns of older clients often have a basis in reality but also may reflect biases, distortions, and exaggerations. The therapist helps the client distinguish between realistic implications of their situation and false beliefs about the situation that lead to excessive negative preoccupation and distress.

The behavioral response to awareness of these dysfunctional beliefs will hopefully motivate the individual to engage in activities and relationships that restore pleasure and to generate ways to overcome barriers to enjoyment. The approach to treatment will draw on standard behavioral techniques, including contracting, monitoring of mood, and monitoring of specific behaviors. This approach enables clients to implement new behaviors in gradual, graduated steps and components. These small, incremental, and reinforced steps enable depressed or dependent clients to begin to move out of a cycle of passive inaction and to make important behavioral changes to enhance their well-being. Behavioral approaches emphasize that clients are experts in their own experiences and skills, draw on common sense knowledge, and avoid psychological jargon.

The therapeutic approach of CBT is one of active collaboration between client and therapist. Sessions are structured and emphasize targeting problems, skills training, and problem solving. 'Homework' requiring practice of new skills is assigned regularly and reviewed in each session. Treatment length is generally brief (10–20 sessions). One or two follow-up sessions are sometimes scheduled for relapse prevention and skills maintenance. The strong emphasis on a collaborative relationship between client and therapist requires significant attention by the therapist on establishing a strong therapeutic alliance with the client.

Rationale for Use of CBT with Older Adults

Appropriate for Addressing Normal Problems of Aging

Older adults experience an increasing number of transitions and stressful life events associated with the normal process of aging. Many of the developmental challenges of late adulthood, such as the need to adapt to sensory and perceptual losses, to cope with the loss of significant others, and to adjust to changes in work and family roles, can occur simultaneously or in close succession, complicating the adjustment process. The success with which older adults adapt to these and similar developmental tasks will likely predict their vulnerability to decreased mental and physical well-being.

CBT has been shown to be helpful as a way to support older adults who experience these developmental challenges as problematic and seek treatment to alleviate their emotional distress. In particular, CBT's problem-solving approach, with its emphasis on the development of coping skills, is ideally suited for helping individuals respond to normal developmental and life-adjustment events.

CBT has also been used successfully with older adults to alleviate symptoms of specific psychiatric disorders, including depression, anxiety disorders, and somatic disorders (e.g., insomnia, sexual dysfunction, chronic pain). Thus, this treatment modality has shown promise in addressing a range of problems that an older population might face as they cope with the challenges of aging.

Appropriate for Older Persons

Before the early 1980s, mental health providers often assumed that the elderly would not benefit from psychotherapy. The belief was that older adults were inflexible and incapable of change. Some even assumed that depression and deteriorating mental well-being were normal conditions of old age. These views have been effectively challenged by many studies that have demonstrated the efficacy of psychotherapy for this population. In particular, research has indicated that therapy with the elderly is most helpful if it is (1) not stigmatizing (with emphasis on coping skills, not on psychopathology), (2) structured (so the client knows what to expect), (3) time limited (providing hope that the individual will soon see improvement), and (4) goal oriented (has a problem-solving focus). CBT meets these criteria and provides an excellent

model for addressing the problems experienced by aging adults. In addition, the collaborative stance and present-focused emphasis of CBT generally make it feel more respectful and appealing to an older population.

Recommended Adaptations and Modifications of Standard CBT for Use with Older Adults

Although standard techniques of CBT can be used with older adults, certain modifications in the implementation of treatment are recommended to accommodate age-related changes in personality and intellectual functioning.

Accommodation to the Unique Experiences of this Population

Heterogeneous Population Older adults comprise a widely diverse and heterogeneous population. Variations in educational level, physical health, intellectual functioning, interests, life circumstances, and social history are often greater than those found in a younger population. Such diversity demands added flexibility and sensitivity on the part of the therapist in obtaining a thorough psychological, social, and medical history. Attention to the multiple factors that may be operating in the situation facing the older adult will enhance the therapist's ability to tailor treatment to the appropriate level and unique needs of a specific older adult.

Age Differences An obvious difference between working with older and younger client groups is the likelihood of an age gap between client and therapist. The therapist must recognize and be sensitive to ways in which age compatibility impacts therapy, particularly in the therapeutic relationship and in the identification of appropriate therapeutic goals. For example, a young therapist may find it difficult to accept treatment goals that might be important for someone who has only 5 or 10 years of life left. The tendency may be to aim for long-term personality change rather than helping the client cope or adapt to an immediate situation.

Modifications to Therapy Process

Slower Pace of Therapy Several sensory and developmental changes associated with normal aging require some adjustment to the pace of therapy. Sensory deficits, including decreased visual and auditory acuity, can affect the rate and accuracy of information processing. The therapist should inquire about hearing loss, speak more slowly, and enunciate clearly. Adjustments to the physical environment, including bright lighting and low background noise, will help compensate for many sensory difficulties.

Developmental changes in the elderly also impact their capacity to learn new information and demand a slower pace in therapy. Research indicates that the elderly experience a gradual decline in their ability to absorb and recall new information, learning at a slower rate or in a different way than younger persons. It is helpful to present important information in several different sensory modalities. For example, using handouts and written feedback or having clients frequently repeat major points will enhance encoding of new information. Asking elderly clients to take notes and write down important information during therapy sessions will also improve their capacity to absorb new material. Pre-therapy cognitive screening of older clients to assess level of intellectual functioning is important to ensure that those with gross deficits (e.g., moderate to severe dementia) are excluded from treatment. Clients with only mild cognitive impairment can still benefit from treatment if proper adjustments are made in method and rate of presenting new material.

Active Role of Therapist When working with older adults, the therapist needs to be more active, particularly in maintaining the focus and structure of the session. Older clients sometimes digress from the task at hand to share additional material not related to the therapeutic objectives or to engage in spontaneous life review. The therapist must use clinical judgment to determine when it is necessary to refocus the topic of discussion and redirect the client to the immediate problem under discussion. Taking an active role, however, does not imply an overly directive or 'pushy' style of interaction that patronizes or infantilizes the older adult. A strong therapeutic alliance is critical for successful outcome.

Socialization to Therapy Older adults differ widely in their level of therapeutic sophistication. Many grew up in a culture that viewed psychotherapy as a treatment for 'crazy' people. They often hold the belief that it is shameful or embarrassing to be in therapy. The therapist should explore the older client's expectations, stereotypes, and fears about the process of therapy in order to elicit potentially obstructive assumptions. For example, many older clients think of therapy as a passive process, like going to the doctor to get 'fixed.' It is, therefore, helpful to educate these clients about the active nature of CBT, which requires their participation and collaboration. The therapist should stress the need for a collaborative relationship, the importance of completing

'homework,' and the structured format of individual sessions. In addition, it is often important to review the special 'rules,' conditions, and safeguards of therapy that might differ from the normal rules governing social interactions.

Treatment Approaches

Treatment of Common Life Stage Problems of Older Adults

Most older adults adapt successfully to the multiple developmental and social changes that are common in late life. For those who experience distress or develop psychological symptoms, CBT offers an ideal treatment modality. The emphasis in CBT on the acquisition of coping skills provides older adults with concrete strategies for dealing with areas of problematic adjustment.

Bereavement Multiple losses are common as people age, including deaths of spouse, family, and friends. A less obvious form of loss involves the change in relationship quality with a spouse or friend who may be experiencing physical or cognitive impairment. These losses, as well as the awareness of one's own mortality, often trigger a review and evaluation of unrealized dreams, lost opportunities, and unresolved relationships. This review may activate negative thoughts and maladaptive schema that impede the recovery process. In addition, the loss of meaningful relationships may isolate the older adult and reduce the opportunities for support and social interactions with others. CBT interventions that seek to address these concerns can be helpful in reversing the negative spiral and engaging the individual in a more positive and adaptive response. For example, cognitive interventions that identify negative thoughts and challenge their accuracy will facilitate a more positive grief reaction and process. If the person believes that 'I can't survive alone,' 'My life is a total failure,' or 'I'll never be happy again,' then the person will find it difficult to interpret experience accurately. Cognitive techniques, such as 'examining the evidence' and 'generating alternative thoughts,' will facilitate a more positive recovery from loss. In combination with behavioral techniques, such as increasing pleasant events and interactions with others, CBT helps move the person into a more problem-solving and adaptive response.

Chronic Illness and Disability The majority of older adults (some estimate as high as 85%) have some type of chronic illness, such as arthritis, diabetes, hypertension, or respiratory or cardiac problems. Many also experience a loss or reduction in physical and intellectual abilities that leave them dependent on others for assistance. These physical changes may impose limitations on their lifestyle to accommodate restrictive medical schedules and regimens, cause chronic pain, strain their coping resources, and/or challenge their sense of self-worth, competence, and control. These limitations pose risks for decreasing the individual's engagement in activities and relationships that bring enjoyment and meaning. If older adults also have negative beliefs about themselves and their ability to cope with their illness, there is an additional risk for developing psychological symptoms.

Adjustments to standard treatment protocols (such as simplification of therapy techniques and use of short, frequent sessions) and consideration of the special needs of this population are usually necessary for successful implementation. For example, disabled older adults may need to be seen in facilities that are wheelchair accessible, have elevators, and have rooms large enough to accommodate walkers or wheelchairs. Treatment in the client's home may also be a necessary accommodation.

CBT that identifies negative beliefs about the illness or disability (such as 'Nobody wants to be around a sick person'), that fosters more adaptive thinking about the situation ('My family and friends still enjoy my company'), and that promotes continued participation in pleasant and meaningful activities will encourage better adjustment and coping with the illness or disability. Thus, CBT offers a promising approach for teaching patients to cope with chronic pain or disability, challenges the perception of being a 'burden,' alleviates somatic symptoms, and enhances positive mood.

Changes in Social and Family Roles Older adults face multiple normative transitions associated with aging that result in changes or losses of important social roles. When the individual's personal identity or feelings of self-worth were tied up in a particular role, the loss of that role can be devastating. From a CB perspective, the way an individual perceives these role changes and the beliefs they hold about their own value and importance outside of these roles will impact how well they negotiate the transition. For example, a person who believes that his or her life is meaningful only if they are making money may respond to retirement with thoughts about no longer having value or being needed.

Normative changes in family structure also occur as the family moves through developmental stages. Intergenerational differences and conflicts are bound to emerge as elderly parents and adult children

renegotiate new roles and relationships. Elderly parents may become depressed if ill health or financial constraints force them to become dependent on children. Conversely, parents may feel hurt or abandoned if they perceive that their children are not available to care for them. Identifying an individual's expectations and assumptions abut the nature of late-life parent–child relationships will shed light on why certain family interactions become problematic.

Marital conflicts can also erupt as couples in longstanding relationships undergo changes in patterns of functioning due to retirement, illness, loss of parenting role, and so on. Couples tend to carve out areas of responsibility over the course of their marriage that may be threatened by the change in status of one partner. In addition, life changes (particularly the loss of the shared parenting role) may leave the couple feeling that they have little in common or have lost a sense of shared purpose. CBT can be helpful in challenging unhelpful or negative perspectives on role and relationship changes associated with aging and can encourage the development of new and positive shared activities and relationships.

Ageism and Low Self-Esteem Today's youth-centered culture fosters a stereotype of old age that is less than flattering and optimistic. Some older adults accept these stereotypes as inevitable truths and believe that being old means being undesirable, unattractive, and unwanted. These beliefs can lead to a sense of futility about the future, a passive acceptance of problems, and a withdrawal from engagement in the larger community. Clearly, CBT that challenges and dispels the myths about aging can help activate the individual into a more positive coping response to these hurtful messages.

Treatment of Psychiatric Disorders

CBT has been used to treat a range of psychiatric disorders in older adults. The most common of these include depression, anxiety, drug and alcohol abuse, and somatic complaints, such as insomnia and chronic pain.

Depression Depression is the most common mental health problem in the elderly. While the incidence in community-dwelling older adults is no higher than in the general population, the risk increases significantly with medical illness or institutionalization. Depression is probably the best researched of the psychiatric disorders in the elderly, with epidemiological evidence indicating that older adults have the highest suicide rate of any age group (one-fourth of all suicides are carried out by persons age 60 or older). There is also a growing awareness of 'silent' suicides among older adults who determine to die through non-compliance with medical treatment or self-starvation. Because depression is the principal risk factor for suicide, it is particularly critical to diagnose and treat depression in the elderly.

Depression is not a normative condition of old age, but is rather a treatable psychiatric disorder in the elderly. Significant research literature indicates that CBT is an effective treatment modality for depressive disorders in both younger and older adults. CBT was specifically developed for the treatment of depression and has been standardized into well-documented treatment protocols. It is often used in combination with pharmacotherapy or supportive or family therapy.

A challenge facing the therapist working with older clients who are depressed is differentiating symptoms of depression from underlying medical problems. In addition, there are several differences in the presentation of symptoms found in depressed older adults that may prevent accurate diagnosis of depression. Specifically, depressed older adults are more likely to report somatic rather than psychological symptoms and to seek medical services rather than psychiatric services for treatment of depression. The typical symptoms of depression often overlap with normative changes associated with aging, such as alterations in sleep, appetite, and physical health. Thus, older adults may go to their physician complaining of physical symptoms such as weight loss or lack of energy without recognizing an underlying depression. In addition, depressed elderly tend to withdraw from social activities, confine themselves to bed, neglect bodily functions, and evidence symptoms of apathy and self-deprecation.

Most CBT techniques have been shown to be helpful in treating depression in older adults. The use of the dysfunctional thought record to monitor the occurrence of negative automatic thoughts, to illustrate the relationship between thoughts and emotions, and to challenge the thoughts related to the patient's negative mood is an effective tool. Behavioral techniques, such as daily monitoring of mood and increased participation in pleasant events, are often helpful early in treatment to break through the depressive inertia, improve mood, and create positive expectations for therapy. Assertiveness training frequently restores a sense of self-efficacy and control for those whose depression is linked to issues of dependency.

CBT for the treatment of depression is usually offered in individual therapy. However, there is a growing body of literature suggesting that CBT approaches work well in group formats for the treatment of depression, especially depression linked to a

specific precipitating event (e.g., loss/bereavement, caregiving for a family member with dementia, coping with a chronic illness). In particular, psychoeducational groups designed to alleviate depressive symptoms through the acquisition of cognitive and behavioral skills have shown promising results. Group approaches have the added advantage of increasing social interaction and contact for isolated or lonely individuals. Research suggests, however, that older adults with severe levels of depressive symptoms would most likely not benefit from a group format for treatment and should be treated with individual therapy.

A current area of interest is the effectiveness of CBT in treating depression in early stage Alzheimer patients. Because depression has been shown to impair cognitive functioning, treatment of depression in Alzheimer patients is warranted and, although not halting the disease progression, can help reduce excess disability in functioning. Cognitive techniques help early stage patients to reduce cognitive distortions and generate more adaptive ways of viewing situations and events. Behavioral interventions are helpful with more moderately or severely demented adults and seek to modify the person–environment interactions by increasing positive activities and decreasing negative ones.

In summary, CBT for the treatment of depression in older adults has a strong research record of effectiveness in alleviating symptoms and enhancing functioning. A multilevel approach is probably most effective for dealing with depression in the elderly, with attention given to both psychological and physical factors.

Anxiety Research indicates that anxiety symptoms are more prevalent in elderly people than in any other age group, occurring at about twice the rate of younger adults. The types of anxiety disorders most common among the older population include generalized anxiety, mixed anxious-depressive symptoms, and phobias (often characterized by exaggerations of rational concerns). More rare are late-life onset of obsessive-compulsive disorder (OCD) and panic disorders.

Treating anxiety in the elderly is particularly important due to the negative impact of anxiety on cognitive functioning. High levels of anxiety can interfere with memory, learning, and attentional capacities in older adults and mimic the symptoms of dementia. Treatment of anxiety is often complicated in older adults due to the frequency of coexistence of depression with the anxiety.

Pharmacotherapy is the most common form of treatment for symptoms of anxiety, despite increasing evidence that the use of benzodiazepines by older patients is associated with increased risk of morbidity, including excess sedation, cognitive impairment, falls, and vulnerability to withdrawal symptoms. CBT, on the other hand, offers a more risk-free approach to management of anxiety symptoms.

Although research into the efficacy of CBT for the treatment of anxiety disorders in older populations lags behind research on the treatment of depression, there is a growing body of evidence suggesting that CBT is effective in managing and reducing symptoms of anxiety. Several different CBT approaches to treatment of anxiety in this population have been described. The target of intervention for most approaches appears to be specific cognitive and behavioral symptoms of worry, specifically excessive worry (especially about aging and related health matters), intolerance of uncertainty, erroneous beliefs about worry, reduced structure of daily life, anxiety over symptoms of autonomic arousal, problem solving, insomnia, and cognitive avoidance. Some interventions also included learning and memory aids designed to enhance the impact of the treatment (e.g., homework reminder and troubleshooting calls, weekly review of all concepts and techniques). Results from these studies are promising, but suggest that standard individual CBT may not be optimally effective and may require enhanced treatment that includes support, reminders, and problem-solving strategies.

While these results show promise in treating symptoms of anxiety in older adults, more work is needed in the development and evaluation of CBT for treating anxiety disorders in this population. The advantages of a non-pharmacological approach to treatment of anxiety in older adults are clear and support the need for further development of alternate models of treatment.

Drug and Alcohol Abuse Abuse of drugs and alcohol is not uncommon among the elderly. The high rate of prescribed medication use, increased physiological sensitivity to drug effects, and the danger of interaction effects of multiple medications and/or alcohol place older adults at high risk for deliberate or accidental misuse of drugs or alcohol. In addition, some older adults turn to alcohol to help cope with stressful life events, thus increasing the risk of addiction or toxic interactions. The risk for addiction may be high due to the relative isolation of older adults who often drink in the privacy of their own home and do not have to keep work schedules that would be noticeably impacted by hangovers or intoxication. Heavy use of drugs or alcohol will place the older adult at increased risk for depression,

illness (including risk for falls and accidents), and cognitive impairment.

While few studies exist documenting CBT protocols specifically designed to treat substance use/abuse issues in the elderly, the CBT model seems an appropriate one for dealing with these concerns. CBT approaches for treating real or potential substance abuse problems might include (1) education regarding the importance of monitoring drug and alcohol consumption, (2) development of strategies for managing complex drug regimens, and (3) acquisition of coping skills for managing negative emotions and stressful life events. Individuals who have a long history of chronic alcohol and drug abuse problems would not be suitable for this treatment approach.

Somatic Complaints (Insomnia, Chronic Pain) CBT approaches to managing the distress associated with physical/somatic problems show much promise. As with anxiety disorders, the treatment of somatic complaints of older clients with pharmacological interventions poses risks. Multiple drug interactions, risk of sedation leading to loss of balance or falls, and addiction are problems that come with use of medication as the sole treatment for these problems. A growing literature on alternate methods of treating or managing these problems suggests that CBT is a promising addition to traditional treatments. For example, common CBT techniques used to treat insomnia include daily sleep diaries, establishment of 'bedtime routines,' and tracking of symptoms with clinical rating scales. CBT approaches to treatment of chronic pain often include relaxation training, use of scaling techniques, and use of distraction or imagery techniques.

Effectiveness of CBT with Older Adults

Research documenting the efficacy of CBT in treating the psychological problems of older adults is encouraging. CBT has been shown to reduce symptoms of depression, anxiety, and somatic complaints (e.g., chronic pain, insomnia) in multiple controlled studies. However, research also has indicated that there may be multiple variables to consider in determining whether CBT is the best approach to use with a specific patient and a specific problem. For example, differential effectiveness of CBT compared to other forms of psychotherapy is less certain. Most studies comparing outcomes across different treatment modalities have limitations that make conclusions problematic. In general, data support that some form of treatment is better than no treatment, thus emphasizing that the elderly can benefit from therapy with success rates that are comparable to those with younger patients.

In addition, a few studies indicate that, although there is little difference across treatment modalities at the conclusion of therapy, long-term maintenance of gains is more likely with CBT. The assumption is that the acquisition of coping skills will generalize to other situations and will enable older adults to adapt more successfully to ongoing life stressors. More controlled studies are needed to test this assumption.

Research examining outcome variables in CBT suggests that certain patient-specific and therapist-specific variables may be linked to successful outcome. For example, some studies have demonstrated that the role of the therapeutic alliance is critical in developing the collaborative stance required for successful CBT and may be the key element in whether the intervention is successful. A mismatch between client and therapist may undermine the effectiveness of therapy. Other studies have explored patient-specific variables that seem to be related to outcome, such as (1) initial intensity of depressed mood, (2) presence of a personality disorder in addition to the depression, (3) depth and quality of social and emotional relationships with friends and/or family, and (4) acceptable level of intellectual flexibility and functioning (e.g., absence of severe cognitive decline or rigidity).

A study comparing CBT and psychodynamic interventions for older depressed family caregivers was one of the first to document a specific patient-by-treatment interaction in predicting outcome (length of time caregiving $\times$ type of therapy). Specifically, the longer the time spent as a caregiver, the more positive the outcome with CBT compared to other treatment modalities. The suggested explanation is that early in caregiving, older adults respond best to an intervention that acknowledges and explores the sense of loss associated with the many changes in current and future plans caused by the illness (psychodynamic therapy). Long-term caregivers, however, whose social and emotional resources are dwindling, may respond better to highly structured, skill-oriented interventions that focus on coping rather than emphasizing their losses (CBT).

Other patient-specific variables associated with CBT outcome with depressed older clients have been noted. For example, individuals who generally respond well to CBT are those experiencing reactive depression in which a clear precipitant can be determined and whose depression can be seen as a response to the specific event or situation. Patients with chronic depression, or with a depressive episode superimposed on dysthymia, can be treated effectively if the goals are modest and the general aim is for improved affective status, rather than complete remission of the disorder. The use of medication in conjunction with CBT and the extension of treatment

to 30 or 40 sessions may also facilitate the rate of improvement in the chronically depressed patient.

Therapist-specific variables that are associated with outcome have been less studied. As mentioned earlier, outcome studies have underscored the importance of establishing a collaborative therapeutic relationship with the client. For a therapist working with older adults, attention to certain issues may enhance their capacity to form a therapeutic relationship with the older client. In particular, it is important that therapists examine their own attitudes toward the elderly for potential biases that might negatively impact the therapeutic relationship. Therapists need to convey respect for the life experiences and accomplishments of the older client rather than making their sole focus the client's current difficulties.

In conclusion, CBT is an appropriate and effective intervention for psychological problems in the elderly. Although modifications to the standard course of treatment may be necessary to accommodate the older client (particularly the format and pace at which new information is presented), older adults treated with CBT seem to show an improvement rate similar to that of younger adults. Additional research into specific factors that contribute to outcome will be helpful in developing more comprehensive CBT models for treating the psychological problems of older adults.

See also: Adaptation; Anxiety Disorders; Bereavement and Loss; Dementia; Depression; Information Processing/Cognition; Learning; Life Review; Mental Health; Self Esteem.

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Comparative and Cross-Cultural Studies

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Glossary

Cross-Cultural Research – Research of an open-ended and qualitative nature within a meaningful ethnic group or community of a specific culture.

Cross-Ethnic Research – Research within one or more distinctive cultural groups within a nation using both quantitative and qualitative instruments to compare the responses for specific contexts. These cultural groups may also have minority status.

Cross-National Research – Research using survey instruments on probability samples to compare the responses of people across nations.

Holocultural Research – Research using a standard sample of world cultures based on secondary data reported ethnographically and organized within the Human Relations Area Files.

Introduction

Gerontology has always had a healthy respect for comparative research. Elders from one context have

been compared with their counterparts elsewhere in order to determine what is universal about growing old and to distinguish what is specific to a particular population and sociocultural circumstance. Although all research is based on comparison (male–female, young–old, rich–poor), cross-cultural research involves a distinctive research design. At a bare minimum, two or more populations with known biological or cultural properties are systematically examined to evaluate hypotheses about how differences shape experiences of aging. Beyond this basic criterion, comparative research is by necessity quite diverse, reflecting the problem under investigation and the variety of contexts in which people live. This article examines the importance of cross-cultural research, the variety of comparative research designs, specific issues that have been investigated among older people, the meaning of old age and the life course, and needed comparative research.

Importance of Comparative Research

Why engage in comparative research? Coordinating data collection and analysis from around the globe is expensive and time intensive. What is the payoff? There are a number of very compelling reasons for comparative research. First, curiosity is a property of the human intellect. What is it like in faraway places, and do they do things better or worse than us? Second, and more important, diversity helps us formulate and clarify questions. If everything were uniform, there would be virtually no reason to ask questions. For instance, if everyone had the same skin color, why would we want to determine the purpose of skin color? Because skin colors range from dark to light, we want an explanation, and thus discover the positive functions of dark skin and ultraviolet ray protection. Likewise, we find that light skin has positive functions in tanning and vitamin D production for bone metabolism. With cultural phenomena, differences are even more important in challenging world views that seem natural and the only way of understanding and doing things. Just like skin color, issues related to old age, such as retirement, pensions, nursing homes, or even Alzheimer's disease, are seen as one way of doing or understanding things, not the only way. Third, by encompassing the full range of human experience, we enrich and strengthen our scientific theories about that experience. For gerontology, if we limit our investigations to nations where old age has been declared a problem, then we are likely to perpetuate the myths these societies have about themselves. By including the full gamut from small-scale foraging societies to the most industrialized societies of Europe and North America, we gain in diversity and challenge the models generated by one societal type. Furthermore, we strengthen our theories by being able to isolate the social and cultural forces that shape the experience of aging in distinct settings. In the end, we can separate what is universal from what is culturally specific to the experience of aging. Finally, we want to learn something about ourselves. We want to see ourselves as 'the alien.' In the relief of other cultures, we comprehend our own with more understanding.

Comparative research is not without its pitfalls. What has become known as the comparative method can be abused. All data collection and analysis must meet standards of data quality control. Most familiar are issues of validity and reliability. Validity is an assurance that the indicators selected are actually measuring what they should be as suggested by the theory under investigation. Reliability is the confidence placed in procedures to abstract from the data through coding to reduce distortion of the idiosyncrasies of the coders on the resulting data. In other words, the coders should have sufficiently explicit understanding of coding categories so that one coder could replicate the work of another coder with minimal variation in results. In addition to validity and reliability, cross-cultural analysis requires guarantees of comparability. With issues of measurement resolved, we still must consider whether what we are comparing across sites is even similar in meaning. For something as fundamental as old age, can we define it in a way that is meaningful to both corporation executives in New York City and peasant farmers in rural Mexico? Generally for primary data, collected first hand by researchers, comparability problems are made explicit through discussion and negotiation. Secondary data taken from existing records present more challenges since investigators must interpret the meaning of the records.

Comparative Research Designs

Comparative research designs fall into two broad categories: cross-national and cross-cultural. Distinguishing these types of research are distinctive methodologies and units of analysis.

Cross-national Research

The intent of cross-national research is to compare people living in different political units or nations. Thus, the unit of analysis is a country sometimes differentiated into rural/urban or into ethnic groups. Researchers select the people who will participate through national probability sampling. These individuals are then asked either to complete a questionnaire or to agree to be interviewed by a

survey researcher using a standardized interview guide. Most often the questions are designed to be efficiently answered and recorded in a closed-ended format. In this format, various answers to the questions are determined in advance so they may be checked off on the questionnaire and transferred to electronic form for data analysis. In contrast, open-ended questions permit more variability in responses, which in turn presents more challenges in categorizing variation. Results from cross-national research are presented using statistical tables to document national differences on a wide variety of issues such as health, family support, and retirement.

Cross-cultural Research

Comparing entire nations is beyond the intention of cross-cultural research. Instead, the units of analysis are more homogeneous cultural units such as ethnic groups, villages, or urban enclaves. Investigators focus on how cultural understandings and context shape the way aging is perceived and experienced. Research strategies are more open ended and involve the use of qualitative methods (as compared to the quantitative designs of survey research). Although quantitative techniques may be used, results are presented in an ethnographic form describing the cultural context along with any statistical information.

Specific research designs for cross-cultural research are quite variable. At one extreme are large-scale research projects involving a team of investigators using the same research design and adapting protocols to several cultural settings. On the other extreme are single researchers designing their research to shed further light on an existing problem or to redefine that issue by investigating it in a different cultural context. Because primary data are sometimes expensive and difficult to obtain, secondary data are very attractive. Existing ethnographies are systematically organized and mined for information relevant to a topic. The most comprehensive endeavor to use published reports as comparative data is the Human Relations Area Files (HRAF). A distinctive comparative approach has evolved that is known as holocultural. This method is based on a sample of 186 cultures that are relatively independent of each other and ethnographically well documented. Alternatively, ethnographic case studies may be selected by a criterion such as region or by societal type to elucidate a topic on a comparative basis.

Old People

Comparative studies of older people began, like gerontology itself, with an assumption that old age was a problematic state of affairs. Among the first tasks were to demographically document the percent of older adults in a society and to ascertain how well they were doing. Subsequently, topics of investigation became more diversified once we understood old people to be among the most heterogeneous of populations.

Demography

Demography is among the most comparative endeavors. The vital statistics and demographic profiles of one nation are interesting but take on new meaning when contrasted with the population statistics of other nations. Through comparison we can understand the dynamics of fertility, mortality, and migration and the factors shaping population size and structure.

Within the past two centuries, world population has been most impacted by the industrial revolution. Increased productivity and demand for workers, combined with improved sanitation and medical technology, resulted in high fertility and remarkable declines in mortality, especially among infants and children. The net result was an exponential increase in world population, with a doubling in every 50 years. Comparative demographics reveal the continuing shock wave of industry. The populations of the nations that experienced industrialization the earliest are now considered to be aging. Initially, their populations were young, but as the rewards for large families declined and child-rearing costs increased, fertility declined. With further reductions in mortality, the formerly youthful population aged, since there were fewer children replacing their parents and grandparents. This phenomenon has been identified as the demographic transition. In nations that experienced industrialization more recently, the demographic transition has not yet occurred; populations are still youthful and expanding. According to projections, the world population will continue to expand until the twenty-second century, when the effect of industry will stabilize with a world population of 14–19 billion.

If advances have been made in extending life and reducing mortality, how long is it possible for a human being to survive? Demographic profiles indicate that surviving to over 100 is rare even in industrialized countries, but is increasingly possible. In at least three non-industrialized village/ethnic groups we find reported extreme longevity of up to and possibly over 130 years. This is an enticing prospect given molecular biological evidence that humans could potentially have life spans of 120–160 years. However, research among the Abkhasians in the

former Soviet Union state of Georgia, the Ecuadorians in Vilcabamba, and the Hunzakut of the Himalayas reveals that people in these areas grow old, but not as old as they claim. Assuming identities of parents to avoid military conscription or using age escalation to claim attention and respect leads a few elders to affirm they are far older than they actually are. In the absence of birth certificates, evidence of real age is difficult to prove without multiple documentations through baptismal records, marriage certificates, birth histories, and connections to known regional and national history. Thus, aside from reports of superlongevity, the nations where people are surviving to become centenarians are the industrialized nations of Europe, North America, and Asia. From this work, we are reminded that age is not just a simple biological or demographic fact, but can be manipulated and is a potent factor in the politics of daily life.

Well-Being and Successful Aging

As gerontology crystallized into a field of specialization, researchers accepted a societal definition that saw aging as problematic. Thus, one important task was to document how well or poor older adults viewed their own lives. Well-being measures, morale scales, and life satisfaction indexes became a major methodological focus and area of inquiry. Cross-cultural research presented immediate challenges to psychometric scales attempting to measure morale because of inherent cultural assumptions about psychological well-being. Comparative research focused on questions about the status of older people, how they are treated, and what is available to them to maintain a position within a community.

It was hypothesized that older people are better off in smaller-scaled tribal and peasant cultures as compared to their counterparts in the industrialized world. A rather obvious point of difference is that older people in industrial countries are expected to retire from the workplace, which removes them from production and a major activity of adulthood. In tribal societies, work is subsistence based and largely domestic. Productive actives are within a family unit and are lifelong until one is no longer able to perform them. This paradise lost hypothesis has not received much substantiation, however. Retirement has not produced social isolation and a life stage that has limited possibilities. Quite to the contrary: due to medical technology, labor-saving devices, and the economic supports in Social Security and pension plans, old age is full of opportunity and possibilities. It is a time of freedom from the responsibilities of younger life stages.

In smaller-scaled cultures, life is less technologically buffered. Where amenities such as indoor plumbing are absent, water must be hauled from a water source instead of turning on the tap. Fuel must be collected instead of setting the thermostat higher. Likewise, a trip to visit a relative may involve a several kilometer walk instead of a ride in a car. Physical demands are higher for everyone, including older adults. In old age, some individuals may well find themselves unwillingly physically active through expectations of their families.

Although we generally find older people to be well-treated and respected members of their societies, abandonment and killing are not rare. In about half of the technologically simple societies, we find practices resulting in the hastened deaths of some older people. Many of these societies are foraging groups who during the harshest seasons may be forced to sacrifice their least productive members for the survival of the group. On the other hand, many of these societies are agriculturalists in temperate climates. Cross-cultural research has revealed that intact, contributing older people are supported and cared for. Once an individual becomes severely impaired and feeble, support is withdrawn. It is a very difficult family decision, often effected at the request of the person who will die. Death may occur violently, as when a son murders his parent, or may happen by abandonment or by withholding food and water.

With older adults experiencing considerable support in most societies, especially in technologically advanced societies, what promotes a good old age? One obvious factor is the physical condition of one's body. As health declines, it becomes increasingly difficult to work and to do one's daily routine. Another factor is security. To be assured that the material basis of life (food, shelter, warmth) will continue into the future and at a level one is accustomed to is a very important component of successful aging. A safety net of support, usually from family, is another ingredient for aging well. Health, security, and support are near universal in their desirability, but how they are actualized and the consequences of deficits in these areas are highly variable. We discuss these in the sections that follow.

Health In promoting well-being, health is very important. Declines in health status are universally feared. Yet on a cross-cultural basis, health is not just the physical status of the body. Health and its understanding are culturally mitigated. Body states are interpreted though cultural knowledge, as is exemplified by menopause. In the late 40s or early 50s, women experience a change in hormones accompanying the

cessation of ovulation. However, across cultures we find major differences in the symptoms signaling the change. In Japan, the most frequent complaints are of shoulder stiffness, headaches, backaches, constipation, chilliness, and irritability. Women in North America report problems with hot flashes, palpitations, night sweats, and tiredness. Unless Asian and European women have different physiologies, changing body states are given cultural meaning.

Across cultures, declining health means decreased functionality. Difficulty in moving, loss of strength, and loss of perceptual acuity are threats to adult status. If one can no longer do that which is expected of most adults, then full participation in social life is compromised. Comparative research again reveals the impact of culture in at least two ways.

First, functionality is culturally defined. Older Americans have to be able to do certain things because of their technological environment and cultural expectations. When one must be able to read and when a significant portion of recreation and information comes from television, then impaired vision is isolating. Likewise, when one can no longer negotiate stairs, cleaning, cooking, shopping, or managing finances, then the ideal of maintaining an independent household is compromised. In other cultures in which literacy is rare and households are jointly organized with extended families, difficulties in vision and in domestic activities are not as threatening.

Second, culture compensates for human frailties through people and technology. Again, we find variation. In technologically simpler cultures, people are more likely to be mobilized. For instance, if one can no longer haul water, the presence of a grandchild who can resolves the problem. In more complex societies with many labor-saving devices, physical frailty is buffered through technology. Not only do machines save time, but also the need of physical strength is reduced. In addition, prostheses such as pacemakers, wheelchairs, glasses, hearing aids, and walkers directly enable people with impairment to continue to do their daily activities. Ironically, even with the ability to reduce the effects of declining functionality with technology, people still fear the frustrations that come with disability.

Security Control over a resource that others value is certainly a very direct way of promoting one's well-being and security. Comparative research has revealed that when older adults are in control of wealth, land, food, the labor of others, and even information, they are elevated in status and face very secure futures. In old age, relatively few can hold on to enough wealth to be able to manipulate kin through the promise of a sizable inheritance. In any culture, we find people who are more than comfortable while others are in need. We also find some economies that work against material accumulation. Under these circumstances, old age can become very trying. When physical abilities have declined, one's access to the very basis of life, food, is at risk. In the abundance of industrialized societies, we find marked wealth differentials, but we also find old age to be economically stabilized through Social Security and social welfare policies. In North America and Europe, older people are less likely to see material issues as threatening their old age.

Kinship and Support Caregiving and support of older people is a major social issue, but it is primarily a family issue. Families look after and, when needed, care for their older members. Cross-cultural studies of kinship have encountered such tremendous variation in family organization that it is almost impossible to come up with a simple definition of marriage or what constitutes a family. Families reflect the economies in which they are located. In nonindustrial societies, kinship plays a much larger role in people's lives. Families are both political and economic units anchoring one in a larger society. Interdependency is reinforced by a domestic division of labor whereby the kin unit manages its affairs for the good of its members, including those who are old. In contrast, kinship diminishes in industrial economies. Lower fertility reduces the number of kin. But more importantly, occupational structures come to dominate people's lives. Individuals participate in industry through an extensive division of labor within bureaucratically organized corporations. With increased wealth, families no longer maintain and rely on a family fund as households become financially autonomous. Families continue to be very important, but the meaning of kinship is quite different. Kin are cherished for their personalities and friendship, not for how much support they can contribute. Parents invest very heavily in fewer children to encourage them to meet their full potential. Very few parents expect their children to return home in adulthood. In fact, a returning adult child can be seen as very problematic.

For caregiving, the preceding contrast would appear to work against older adults in industrialized society. Families have been the traditional safety nets for older people. In industrialized societies, families are smaller. Households are residentially separate and are financially autonomous. Solidarity is based on affect, which is not necessarily the best way to mobilize people because sentiments can change very rapidly. Yet the news is not all bad. Families in North American and Europe go to great lengths to care for

their older members. Also, as states and economies became more complex, a new safety net appears in the market. Virtually everyone in an industrial economy satisfies their basic needs – food, clothing, shelter – by purchasing them in the marketplace. For older adults, the market is basic and continues to complement what family members contribute. Domestic help, lawn services, and even home care can be hired, which help in reducing the caregiving burden for kin. A rather obvious catch-22 is that there must be sufficient financial resources to access the market.

Old Age

Definitions

One of the most striking aspects of age on a worldwide basis is the limited distribution of its explicit use in organizing social life. Aging is a temporal process. Time is culturally configured. With technological sophistication, time can be measured and finely calibrated from milliseconds to millennia. Hours, days, and years are the more meaningful units. For most of human history and the majority of small-scaled cultures, time is not an important dimension of life. Only bureaucratically organized industrialized cultures use time to organize daily schedules and age to regulate their populations. In these cultures, people need to know their ages and thus are issued birth certificates. People of specified ages are expected to be in school, serve in the military, be able to drive, drink, and vote, and be entitled to Social Security. For people living in these contexts, age is very important.

Also on a comparative basis, old age has been difficult to define. Most industrialized societies set their pensionable ages in the early to mid-60s. Thus, old age has a chronological marker. Gerontologists, however, were quick to point out that in spite of its impartiality; chronological age was a poor predictor of ability. Functional age is far more meaningful in terms of what people can do in their daily lives. In cultures in which chronological age is rarely known, functionality is what defines old age. In nations with youthful populations and in which vital statistics are kept, chronological thresholds are lowered to the mid-50s or even the 40s.

Life Course

One of the major theoretical breakthroughs in gerontology has been the emergence of the life span perspective. Initially, gerontology coalesced with a focus on old age. Old age and all its diversity cannot be isolated from the rest of adulthood. Consequently, the life course became a major unit in gerontological research. Cross-cultural research challenges the way we have modeled the life course.

A long-standing problem in social anthropology suggested ways in which age can be formalized into an explicit principle of social organization. A number of small-scale societies make relative age a criterion by which the males are organized into age-stratified groups. Cohorts of boys are initiated into an age class. These classes are sometimes called age sets or generation sets and are bounded groups that are opened for recruitment and then closed once they are complete. A more junior set is then opened. All men are members of a set, and sets are ranked in seniority – boys, warriors, householders, elders, and so forth. The specifics of how the age classes are organized are quite variable, but in the formality of age organization such concepts as age grading, age stratification, and age norms were documented in simpler social contexts and sharply defined.

Life courses are seen as role courses ordered by age norms and expectations. Cohorts enter adulthood upon completing a finely age-graded system of formal education. Jobs and marriage signal full adult status. Within families, generations become more distinctive due to lower fertility and childbearing occurring most commonly in the 20s or very early 30s. Within jobs, we find seniority and for some career ladders based on seniority, experience, and greater responsibility. A new stage is entered with retirement and an exit from the labor force. Although individual role courses are variable, life courses are seen as sequenced and staged. The life course is divisible into intervals distinguished by age-sensitive status transitions.

Age class systems and a staged life course appear to be parallels in differing cultural contexts. Beyond defining graded categories, the similarity vanishes. Age classes are political institutions organizing males in a public arena. For the most part, they are most salient in the junior classes; they see diminishing significance for the more senior males. Age classes do not organize all of life and usually only indirectly affect women. The staged life course is a near-universal expectation from youth to old age. This view of the life course is also restricted to industrialized societies, especially to the middle classes of those societies. People in small-scaled societies do not see life as sequenced through life stages. Age-sensitive roles are not clearly demarcated. Formal education is rare and not universal, thus there are no finely age-graded classes. Wage labor is intermittent, and there is no real job market. No one retires from subsistence activities. Fertility is higher, and families are

much less differentiated by age, with siblings who may be separated by 20 or more years. Under these circumstances, people have life courses that note youth and old age, but they are more functionally and individually defined. Even in industrialized societies, people who are marginalized in poverty aspire to, but find difficult to attain, a sequenced life course.

Needed Research

Gerontology is at a very important juncture as a discipline. In the half century of work thus far, the multidisciplinary effort in gerontology has evolved an ambitious agenda involving research, application, and advocacy. Those who invented gerontology did so working from disciplinary perspectives that set out to define the problem of old age and how to improve quality of life, both physically and socially. From our current perspective, it is not too surprising that we found no modal old person, but incredible diversity in the experience of growing old. We are just now on the threshold of discovering processes that define age and shape how people experience aging. Now more than ever comparative research is needed.

Research

Comparative research reminds us that world populations are remarkably diverse biologically and culturally. With the mapping of the human genome and breakthroughs in molecular biology, we know that populations differ genetically. Biological models of aging are dealing with an intrinsically difficult problem in differentiating genetic from environmental factors. Unfortunately, most of our models are either based on animal data or from people in North America of European descent and who are predominately male. Given the technology available, more progress can be made by examining human variation and diversity over the life span in genetically diverse populations.

Social and cultural research emphasizing diversity is also required. Our understanding of age and life courses is primarily rooted in one type of social context, urbanized industry. To more fully understand the processes that result in age being such an important aspect of these complex nations, we must examine other contexts. Smaller-scaled societies, developing nations, ethnic diversity, minority groups, and local level communities provide a natural laboratory in which to investigate the meaning of age and the role it plays in people's lives. Likewise, we should explore the meanings people who are old find in their lives. Since meaning is cultural, diversity will further add to our understanding of the linkage between cultural context and personhood.

Societal Transformation

Much of our interpretation of global differences in aging has been couched in a theory of modernization. Underlying most of this thought is the optimism of the 1960s, which spawned economic development programs with the intent of hastening the transformation of underdeveloped countries to become industrialized. By the 1990s, we realized that this has not happened and probably will not happen. On the other hand, we recognize that economic change continues, but not as predicted by modernization. Globalization of the world economy is changing life in both the developed and underdeveloped world. Automation has eliminated many jobs in heavy industry and in the service sector. Jobs are being sent overseas to industrial zones in Asia and Latin America. In what is becoming a global assembly line, what happens to age? How are these changes affecting people who are now old in both the developed and underdeveloped world? How are altered life chances shaping the lives of those who are entering adulthood, and what are the implications for their aging? The time to study a phenomenon is as it is happening.

Globalization itself is a force that is altering the use of the comparative method. Very few people live in small-scaled societies and engage in subsistence agriculture or pastoralism or even forage for a living. By the middle of the twentieth century, the young and middle-aged had found wage labor in the cities or in commercial agriculture. Tribal peoples became peasants and peasants became an urban poor. The exoticness of tribal societies is increasingly replaced by the ordinary life of working people. Cross-cultural is more and more cross-ethnic and cross-minority research. Regardless of the global spread of capitalism and the attractiveness of markets, however, cultural diversity will never disappear. As the world changes, cross-cultural research will also change. New questions will be asked to explore the diverse experience of aging in a globalized world.

See also: Demography; Gerontechnology; Life Course; Psychological Well-Being; Retirement; Social Networks, Support, and Integration; Social Security.

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Conditioning

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Glossary

Classical Conditioning – A type of learning in which a neutral stimulus is paired and becomes associated with a stimulus that consistently evokes a reflexive behavior, and becomes sufficient to produce that behavioral reflex.

Conditioned Response (CR) – In classical conditioning, a learned response to a previously neutral stimulus.

Conditioned Stimulus (CS) – In classical conditioning, an originally irrelevant stimulus that after repeated pairings with an unconditioned stimulus comes to elicit a conditioned response.

Delay Conditioning – A classical conditioning procedure in which the conditioned stimulus is presented prior to and remains activated until after the onset of the unconditioned stimulus.

Interstimulus Interval (ISI) – The amount of time that elapses between the onset of the conditioned stimulus and the onset of the unconditioned stimulus in classical conditioning.

Operant Conditioning – A type of learning in which a behavior becomes associated with and influenced by a consequence.

Trace Conditioning – A classical conditioning procedure in which the conditioned stimulus terminates prior to the onset of the unconditioned stimulus.

Unconditioned Response (UR) – In classical conditioning, the unlearned and naturally occurring reflexive response elicited by the unconditioned stimulus.

Unconditioned Stimulus (US) – In classical conditioning, a stimulus that naturally and consistently triggers a reflexive response.

Introduction

Classical and operant conditioning are fundamental forms of associative learning that enable an individual to adapt to a changing environment across the life span. In classical conditioning, a neutral or conditioned stimulus (CS) is paired in time (commonly preceding it by a half second) with an unconditioned stimulus (US) that reliably elicits a reflexive response termed the unconditioned response (UR). Over training, the subject associates the CS and US to eventually produce learned or conditioned responses (CRs) that are behaviorally similar to the UR but that are elicited by the CS. Classical conditioning procedures

were first described by Ivan Pavlov over a century ago and were subsequently demonstrated in a landmark study by Watson and Raynor in which a laboratory animal (CS) that initially evoked no discernable response was paired with a loud, unexpected noise (US) that reliably evoked a fear response (UR). The naive child subject quickly associated the CS and US to exhibit a learned fear (CR) of the previously non-threatening animal. Classical conditioning has been postulated to explain common phenomena such as phobias and avoidance of dental or medical appointments, and it is currently employed in therapeutic procedures such as systematic desensitization (the extinction or loss of an unwanted CR through non-reinforced exposure to the CS). Operant (or instrumental) conditioning occurs when the probability or frequency of a behavioral response is altered by consequences. The likelihood of a behavior to recur will increase when the consequence is either a desirable event (positive reinforcement) or the removal of an undesirable event (negative reinforcement). In contrast, the likelihood decreases when the contingent event is an undesirable event (punishment). Operant conditioning underlies a considerable proportion of behavioral adaptation across the life span and provides the basis for therapeutic interventions involving behavior modification. Age-related changes in classical and operant conditioning have been extensively investigated.

Classical Conditioning

A common laboratory model of classical conditioning involves the pairing of an auditory (tone) CS with an air puff US delivered to the periorbital region to elicit a reflexive eyeblink (UR). In general, subjects quickly associate the CS and US and develop eyeblink responses to the tone CS with relatively brief training. An extensive review of the rabbit nictitating membrane preparation has been provided by Gormezano, and classical conditioning studies have expanded to involve a wide variety of species (including rat, cat, and human) as well as diverse behavioral responses (including leg flexion, jaw movement, and spinal responses). Parametric investigations have clearly demonstrated a strong impact of stimulus sequence and timing on the acquisition of classically conditioned responses. In classical delay conditioning, there is a short delay between the onset of the CS and the onset of the US (typically on the order of 250 to 500 ms). Generally, subjects quickly and effectively learn in a delay procedure. In classical trace conditioning, a brief gap occurs between the offset of the CS and the onset of the US. Conditioning occurs more slowly with this method, and a significant fraction of apparently healthy, young subjects often experience difficulty or fail to learn the association. The interstimulus interval (ISI), or temporal gap between the onset of the CS and onset of the US, has been shown to have significant effects on the rate of learning. Very short or very long ISIs have been shown to be less effective or ineffective in producing learning. Other procedures, backward conditioning (in which the US precedes the CS) and simultaneous conditioning (concurrent presentation of CS and US) fail to induce learning. The effects of aging on the acquisition and retention of classically conditioned responses have been extensively documented in both delay and trace conditioning procedures.

Studies in Aging Animals

Aged rabbits exhibit a modest impairment in the acquisition of classically conditioned responses when a delay paradigm is employed. An enlightening study by Joan Coffin and Diana Woodruff-Pak revealed that older animals required significantly more trials to reach a criterion of eight conditioned responses in a consecutive nine trial training block, but when the number of conditioned responses given during the entire training period was examined, no significant age difference was found. In contrast, the effects of aging appear to be exacerbated when a trace conditioning paradigm is employed. Solomon and associates directly examined the effects of delay and trace conditioning procedures on different age groups. They found an overall effect of age on the acquisition of CRs, but noted greater impairment in the trace procedure that was evident earlier in the life span. Moreover, the age-related deficit in the trace procedure was far more pronounced than that found in a long delay procedure. Consequently, aged animals show impaired learning in classical conditioning that is influenced by the apparent difficulty of the association; deficits in classical trace conditioning are far more severe than in simpler delay conditioning. In both delay and trace conditioning procedures, age-related differences in acquisition emerge early in adulthood. Numerous studies have reported statistically significant differences in rabbits as young as 2 to 3 years old (in a species with a potential life span exceeding 10 years).

Coffin and Woodruff-Pak also examined the long-term retention of classically conditioned eyelid responses in aged rabbits. They found no significant effect of age on overall retention of CRs at 12 or 18 months after training. However, it was noted that younger subjects maintained a relatively consistent performance level across the training periods; older

subjects showed marked improvement in reaching criteria across the phases of testing. Consequently, aged animal subjects display significant delays in the acquisition of classically conditioned responses but demonstrate intact retention once an association has been formed. Their performance in acquisition is differentially affected by the degree of difficulty inherent in the procedure. While both younger and older subjects require more training to reach criteria when a trace procedure is employed, older subjects are more substantially affected. Effects of aging on classical conditioning of human subjects have been extensively described as well.

Studies in Aging Humans

Analyses of age-related effects on eyeblink conditioning in humans began in the 1960s. Early researchers were surprised to find that older adults were significantly impaired in this simple form of associative learning. More recent studies by Woodruff-Pak and others have confirmed significant impairments in the acquisition of classically conditioned responses using a simple delay procedure. Controlling for extraneous factors, including pathology, sensory, and motor functions, researchers consistently note a significant deficit in older groups. Comprehensive analysis of acquisition performance across the life span has revealed that deficits are apparent in relatively young adults. Acquisition rates decline in subjects in their 30s, are marked in subjects in their 40s, and are relatively stable but remain impaired for the rest of the life span (static rates from the 40s through the 80s). Interestingly, deficits emerge at approximately the same relative point in the life span as in the rabbit studies. It should be noted that considerable variability in performance exists within age groups. Determination of the factors involved in the impairment exhibited by a possible subset of aged subjects may reveal the causes of decline. Regression analysis has shown that the age of the subject is the most salient variable in changes across age groups. Reaction time and implicit memory performance did not account for a significant proportion of variability in learning rates. However, cerebellar function, as measured by a timed-interval tapping task, did account for a significant proportion of variability. Given the prominent role of the cerebellum in classical conditioning, this effect is consistent with findings of studies of the anatomical foundations of classical conditioning.

The exacerbation of an age-related acquisition deficit in classical trace conditioning has been reported in human studies as well. A number of studies have shown a robust decline in performance in older subjects, but findings tend to be less consistent than the animal data and the impact of the trace procedure may be somewhat diminished. Further, interpretation is complicated by relatively complex effects of the ISI on learning rates. In contrast to the delay conditioning procedure, extension of the ISI in trace conditioning of human subjects appears to attenuate age-related changes in acquisition rates. Finkbiner and Woodruff-Pak reported that a deficit occurred only in older and not in middle-aged subjects. With the longer ISI conditions, acquisition rates of younger subjects declined, whereas the rates of older subjects were more consistent across ISI conditions. The researchers suggested that both reaction time differences and the engagement of higher cognitive processes may contribute to these findings in humans.

Ultimately, extensive evaluation of classical conditioning in both animal and human subjects has shown a ubiquitous decline in the initial acquisition of CRs that emerges relatively early in the life span. Similar results are noted in discrimination learning studies wherein a non-reinforced CS is employed to evaluate the ability of subjects to differentially develop CRs to the reinforced CS but not to the non-reinforced CS. Results from fear conditioning studies are relatively consistent with findings in human trace conditioning. When higher order cognitive functions such as awareness and general arousability were accounted for, age-related differences were diminished. Retention of learned responses does not appear to be significantly affected by age, and no definitive change in the extinction of CRs has been reported in older subjects.

Studies in Disease States

Classical conditioning performance has been examined in subjects with a wide range of neurological disorders. In Alzheimer's disease (AD), progressive deterioration of the central nervous system produces a concomitant decline in intellectual and cognitive functioning. Woodruff-Pak and associates have extensively examined acquisition of classically conditioned eyeblink responses in patients with AD. They found that AD patients are markedly impaired in acquisition when a delay procedure is employed and somewhat less impaired when a trace procedure is employed, which is consistent with the general effects of aging on acquisition rates. However, in both procedures, AD patients perform more poorly than healthy older controls. Consequently, classical eyeblink conditioning appears to be a sensitive, inexpensive, and non-invasive test for potential AD.

The ability of classical conditioning to differentiate AD-related deficits from other types of dementing

disorders has been evaluated. Significant differences were noted between AD patients and patients diagnosed with cerebrovascular dementia (CVD). AD was found to produce significantly slower acquisition rates in comparison to the performance of patients with CVD. In addition, AD patients displayed less variability in CR onset latency in contrast to CVD patients. Since CR onset typically follows a systematic pattern wherein onset occurs near the onset of the US and progressively decreases in latency as learning develops, it is feasible that the AD patients display both associative learning and response timing deficits during classical conditioning. The effects on timing could reflect a loss or disruption of the typical pattern of hippocampal neuronal activity that correlates with the amplitude and time course of the behavioral CR. The sensitivity of classical conditioning in detection of early presymptomatic AD is evident in several important findings from Woodruff-Pak and her laboratory. In one study, 62.5% of apparently healthy older subjects with impaired acquisition rates were subsequently diagnosed with dementia within three years of the evaluation. Another report described a case in which a significant deficit in classical conditioning preceded detection of dementia by other screening methods by 6 years. Subsequently, it would appear that AD has early, profound effects on acquisition in classical conditioning and that the severity of the deficit may be capable of differentiating among types of dementia. Eyeblink conditioning would provide a non-invasive and relatively non-threatening means to identify early AD cases and could provide a sample of subjects in which to evaluate potential interventional treatments (see **Figure 1** and **Table 1**).

Operant Conditioning

Common examples of laboratory models of operant conditioning include early studies of pigeon key pecks reinforced by grain or rat bar presses reinforced by food pellets. As in classical conditioning, timing of events has a profound effect on performance. Long delays between the target behavior and the consequence undermines the association. In addition, the schedule of reinforcement influences the rate of learning as well. Under continuous reinforcement, in which every response is rewarded or punished, subjects alter the frequency of the behavior quickly. Intermittent reinforcement schedules slow the initial acquisition of learned behaviors

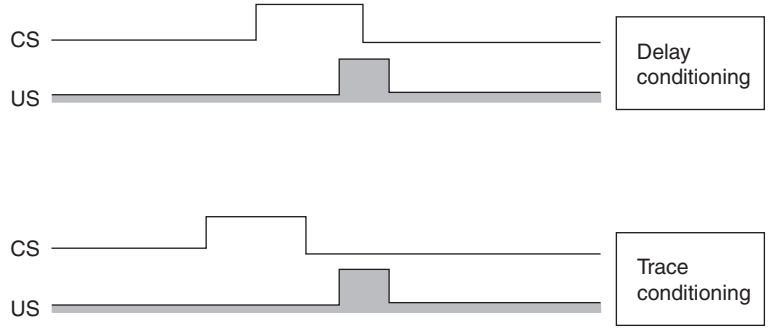

Figure 1 The temporal relationships between conditioned stimulus (CS) and unconditioned stimulus (US) in delay and trace conditioning.

Table 1 Schedules of reinforcement

	Ratio	*Interval*
Fixed	Reinforcement after a fixed number of responses	Reinforcement for first response emitted after a fixed interval of time has elapsed
	Results in a brief pause after reinforcement, followed by a high rate of responding until the next reinforcement delivery	Results in initial slow rate of responding that increases to rapid responding as the time for reinforcement draws near, followed by a pause after reinforcement delivery
	Low resistance to extinction	Low resistance to extinction
Variable	Reinforcement after an unpredictable number of responses	Reinforcement for first response emitted after an unpredictable amount of time has elapsed
	Results in continuous, rapid responding with minimal or no pause after reinforcement delivery	Results in a consistent, slow to moderate rate of responding with minimal or no pause after reinforcement delivery
	Most resistant to extinction	High resistance to extinction

but produce associations that are far more resistant to extinction processes.

In partial or intermittent reinforcement schedules, responding is reinforced only some of the time. In situations that employ ratio schedules, reinforcement depends on the number of responses made by the subject. In contrast, during interval schedules of reinforcement a response is rewarded or reinforced after a specified amount of time has elapsed. A particular schedule of reinforcement determines a subject's pattern of responding. Intermittent reinforcement results in a persistence of responding.

Under a fixed ratio (FR) schedule of reinforcement a reward is delivered after a fixed or predictable number of responses are made. Technically, a continuous reinforcement schedule is a fixed ratio schedule that involves a ratio of one response per reinforcement. Under continuous reinforcement, responding occurs at a steady rate but is interrupted by unpredictable pauses and a drop in the response rate to a moderate level of responding. A different response pattern occurs when a fixed ratio schedule greater than one (i.e., rewarding every second or fifth response) is employed. After each reinforcer is delivered there is a pause in responding, followed by a quick resumption of responding to a constant and rapid rate that is maintained until the next reinforcer is delivered. With a variable ratio (VR) schedule a reinforcer is delivered after an unpredictable number of responses. Reinforcement depends on the number of responses made; however, a variable number of responses is required for the delivery of each reinforcer. A more steady pattern of responding occurs because the response criteria for reinforcement are unpredictable, and pauses in the rate of responding, such as those that occur with FR schedules, therefore are also less likely to occur. Using a fixed interval (FI) schedule the first response after a fixed amount of time has elapsed is reinforced. Reinforcement is available at fixed intervals of time but delivered only if the required instrumental response is performed. Typically the response rate is slow until the end of the time interval. The response rate increases as the time of availability of the next reward draws near. Under a variable interval (VI) schedule reinforcers become available after unpredictable time intervals. The response must be performed after the variable interval in order to gain access to the reward. Variable interval schedules promote steady, stable rates of responding.

Studies in Aging Animals

The effects of age on the acquisition of operant conditioned behavior have been delineated and are strikingly similar to effects seen in classical conditioning studies. Using a continuous reinforcement schedule, we have found that aged rats are markedly impaired in the initial acquisition of appetitively reinforced bar press responses. The magnitude of impairment is similar as well in that aged groups took three or four times as many training days to reach criteria in comparison to the younger group. The impairment appears to reflect an associative learning deficit, in that initial activity levels were equivalent between groups (precluding the potential that younger animals were more active behaviorally and thus produced spontaneous reinforced behaviors earlier in training than the aged subjects). Further, once an association had been formed (meeting a criterion of more than 60 responses in a 20 min training session), response rates were equivalent between groups and precluded the possibility that a lower 'ceiling effect' or maximal response rate in aged subjects had an influence on acquisition performance.

Analysis of the extinction of operant responses in aged rats has revealed no significant difference in comparison to younger subjects. Older subjects were equally resistant to initial extinction via non-reinforced training sessions. Thus, once a behavior was acquired, older animals were unimpaired in maintaining the association. When animals were retrained in the same task, older animals reacquired the response as expediently as the younger animals did. Minimal retraining was required to reintroduce the behavior in both aged and young groups. Cycles of reacquisition and extinction training revealed the expected increased resistance to extinction in both groups as a consequence of prior learning experience. Consequently, the effects of aging on simple appetitive operant conditioning appear to be selectively restricted to the initial learning of the association, and no significant differences are apparent in extinction or relearning of the task.

A differential reinforcement of low rate (DRL) schedule is a more complex appetitive conditioning task wherein subjects must inhibit responding for a period of time to reactivate reinforcement. Commonly, animals are required to inhibit the response for a period of 6 consecutive seconds prior to reinstitution of the reward. Aged animals show a marked impairment in the initial acquisition that is similar to that seen in simple appetitive conditioning. Older subjects experienced significant difficulty in inhibiting responses during the interval. As with many other tasks, once the task was learned, the performance of aged animals was equivalent to younger subjects, and aged subjects were not impaired in the retention of behaviors learned in a DRL schedule.

Aversive conditioning involves the application of punishment to alter the probability of a behavior recurring in the future. In active avoidance conditioning, the subject receives a mild electric shock if they fail to perform the targeted behavior (for example, move to a different location). In passive avoidance, animals are trained to inhibit their natural tendency to explore the environment by punishment for failure to remain at one location in the training chamber. Studies of both active and passive avoidance training revealed a rather marked impairment in aged animals in the initial acquisition phase of training. Once an association is well established, aged animals typically perform as well as younger subjects.

Studies in Aging Humans

Historically, operant conditioning has been used extensively to alter behavior in juvenile and developmentally disabled subjects in the form of behavior modification programs. Early behavioral psychology embraced learning, most often in the form of operant conditioning, as a source of normal and abnormal behaviors and as a method for behavioral change (intervention). However, extensive analysis of performance of adults in operant conditioning has been limited by appropriate control of extraneous variables (motivation, engagement of higher order processes, etc.). Early studies, often using monetary reinforcement, described an apparent deficit in aged subjects that was detected in the initial acquisition phase. Eventually, aged subjects performed as well as younger subjects, and modest to no significant effects were noted in maintenance of conditioned behavior.

More recent analysis of operant conditioning in adult humans has included analysis of patients with traumatic brain injury. Brain-injured adults were found to be somewhat impaired in initial performance, displaying reduced sensitivity to response-reinforcer contingencies. Providing additional 'signal' stimuli enhanced the performance of a subset of the brain-injured subjects, suggesting that some of the deficit may be related to diminished reactivity to the environment in the injured subjects. While data are sparse in comparison to the study of classical conditioning in humans, effects of age on instrumental conditioning appear to be relatively similar. The prominent deficit appears to be restricted to the initial acquisition (association) phase and less prominent to absent thereafter. Considerable effort has been devoted to the elucidation of the neurobiological substrates underlying associative learning. Insight into the fundamental mechanisms mediating classical and operant conditioning may assist in the understanding of and intervening in age-related changes in acquisition (see **Table 2**).

Table 2 A comparison of the effects of aging on the acquisition and retention of classically and instrumentally conditioned responses in both animal and human subjects

		Animal	*Human*
Classical delay conditioning	Acquisition	Aged animals exhibit a modest impairment in acquisition	Older adults exhibit significant impairment in acquisition
		Age-related deficits apparent early in adulthood	Age-related deficits apparent in young adults
	Retention	No significant effect of age on long-term retention	No significant effect of age on long-term retention
		Demonstrate intact retention once an association is formed	Learned responses not significantly affected by age
Classical trace conditioning	Acquisition	Age-related deficits more severe than in delay procedures	Age-related deficits in initial acquisition may be exacerbated in trace procedure
		Impairment apparent earlier in life span; older subjects more profoundly affected	Impairment apparent early in the life span
	Retention	No significant effect of age on long-term retention	No significant effect of age on long-term retention
Operant conditioning	Acquisition	Aged animals impaired in initial acquisition of response under a continuous reinforcement schedule	Aged human subjects exhibit deficits in initial acquisition of conditioned behavior
		Effects of aging restricted to initial learning of the association	Prominent deficit restricted to the initial association phase
	Retention	Once a behavior is acquired and an association established, older animals show no impairment in maintaining the association	Modest to non-significant effects are observed in older subjects in the maintenance of conditioned behavior

Neurobiological Foundations

Considerable basic research has focused on determining the specific neurological networks and changes in brain systems involved in associative plasticity. Pioneering efforts by Karl Lashley, as reported in 1950, were largely unsuccessful in discovering the critical sites in the brain that mediated associative learning. Despite a lengthy, systematic series of studies evaluating the impact of lesioning an array of different brain structures, Lashley was unable to completely prevent the development of learned behaviors in rats. This failure led to his postulate of 'equipotentiality' within the nervous system, which suggested that spared brain tissue adjacent to the damaged region possessed the potential to assume the function previously served by the lesioned area. Subsequently, extensive efforts in describing the fundamental substrates of classical conditioning have led to a relatively impressive understanding of the structural and functional changes in brain systems that appear to form the basis of behavioral changes induced by learning. Studies of operant learning have been markedly less common and fruitful but have revealed some similarity in the processes and brain structures involved in behavioral learning. Examination of these systems and functions in older subjects may help to reveal the sources of the persistent impairment observed during the initial acquisition of learned behaviors.

The Hippocampal Formation

The mammalian hippocampus has long been associated with cognitive processes. Early attempts to control severe seizure disorders in humans by bilateral surgical removal of brain tissue including the hippocampal formation had the unintended result of profound anterograde amnesia. Extensive examination of neurological activity during classical conditioning of the rabbit eyeblink response has led to a comprehensive understanding of the cellular basis of the learned behavior. Early studies revealed a learning-dependent increase in the activity of neurons within the hippocampal formation. Elevated excitability occurred early in training and produced a temporal pattern of activity that was nearly perfectly correlated with the emergence and amplitude of the behavioral conditioned response. However, since classical delay and operant conditioning are unimpeded in animals with bilateral lesions of the hippocampal formation, the relevance of this activity was not clear. Subsequent studies have indicated that the hippocampus (and related neuronal activity) appears to be critically involved in associations in the classical trace procedure. At a cellular level, this learning-related change in activity within the hippocampus is known to be mediated by a subset of glutamate receptors identified as N-methyl-D-aspartate (NMDA) receptors. This associative cellular process, long-term potentiation (LTP) of synaptic efficacy, appears to make a significant contribution to classical conditioning. Experimental induction of LTP has been shown to facilitate, and pharmacological blockade of the receptor sites appears to disrupt, simple classical conditioning.

A number of studies have observed an increased level of hippocampal neuronal activity during operant conditioning. As in classical conditioning, the increase is learning dependent and the pattern correlates with the behavioral response. In appetitive operant conditioning in rats, we have found that initial acquisition by adult subjects is unaffected by pharmacological manipulation of NMDA receptors (agonism and antagonism). Electrically induced LTP also failed to influence the rate of acquisition. However, during extinction of the operant response, an NMDA agonist increased, and an antagonist decreased, the level of responding. Thus, NMDA-dependent hippocampal LTP appears to play a prominent role in the initial acquisition of classically conditioned responses (which is slower in older subjects) but does not appear to have an impact on the initial acquisition of operant behavior (which is also impaired in older subjects).

Examination of hippocampal neuronal activity during classical trace conditioning of aged rabbits was conducted by Woodruff-Pak and associates. Consistent with the previous behavioral studies, aging subjects were significantly impaired in the acquisition of conditioned responses. Thirty-month-old subjects took roughly three times as long as 3-month-old subjects to reach criteria, and 45-month-old subjects took approximately four times as long. In older subjects, hippocampal neuronal activity developed much more slowly but eventually produced the correlated pattern of activity that was observed in younger subjects as a consequence of learning. Consequently, both behavioral and neuronal components of successful classical conditioning are delayed in older subjects, but with adequate training, they develop to the same levels seen in younger subjects. Consistent with a vital role in spatial and higher order cognition, the hippocampal formation appears to play a prominent role in some forms of basic associative learning processes as well. A prominent role in age-related changes in learning is supported by the sensitivity of the hippocampus to stress-related hormonal insult. Indeed, Sapolsky suggested that age-related changes in cognition may be related to an accrual of damage to the hippocampus. The structure

is highly sensitive and reactive to stress hormones, is involved in feedback regulation of stress hormone levels, and shows significant neuronal loss as a consequence of prolonged elevated levels of stress hormones. Anatomical and functional changes within the hippocampus across the life span, along with a prominent role in associative learning, make the structure a prominent candidate for at least some of the age-related differences in learning performance.

The Cerebellum

Historically, the cerebellum has been associated with motor functions, the production of motor programs (coordinated movements) and fine motor control in particular. Richard F. Thompson and associates confirmed an essential, fundamental role of the cerebellum in the acquisition and maintenance of classically conditioned responses in rabbits. Similar to the findings in the hippocampal studies, neuronal activity within the cerebellum produces a learning-dependent pattern of activity that is highly correlated with the amplitude topography of the learned response. Damage to the cerebellar region prior to training blocks the acquisition of CRs, and damage after training produces a loss of conditioned responding that is highly similar to the gradual decline in responding seen in extinction procedures. Intracranial cerebellar stimulation has proven to be an effective CS and US, and is fully capable of producing classically conditioned eyeblink responses. Anatomical data from rats indicate a 15% decrease in the number of Purkinje cells at 2 years of age and a 20% decline by age 3. Thus, similar to the hippocampus, the cerebellum is vitally involved in simple learning and is at significant risk of progressive anatomical decline across the life span.

Analysis of cerebellum volume using MRI was conducted by Woodruff-Pak and associates. It was discovered that cerebellum volume measures in both young and aging subjects were highly positively correlated with behavioral performance in eyeblink conditioning. Specific atrophy within the cerebellum was strongly associated with declining learning performance. The apparently critical requirement of an intact cerebellum for classical conditioning and the well-documented decline in cerebellar structure and function across the life span make the cerebellum of primary interest in age-related deficits in classical and perhaps some aspects of operant conditioning.

Interventional Strategies

Two diverse means of influencing both cognitive processes and related brain functions involve experiential and environmental factors and direct pharmacological manipulation of neuronal transmission. First, profound effects of early environmental deprivation and enrichment on neurological and cognitive processes are extensively defined in developing and younger subjects. In addition, recent cognitive activity may have beneficial effects on subsequent learning performance; this is not entirely unexpected, since learning experience is known to alter functional properties of brain systems subserving cognitive processes. Experientially induced LTP may have effects similar to the facilitatory effects of experimentally (electrically) induced LTP. Second, direct pharmacological manipulation of the neuronal systems affected by aging and contributing to learning processes represents a potential means of attenuating age-related decline in learning performance. Experiential and environmental impact may reflect a naturally occurring facilitation of the same synaptic processes within the brain systems that ultimately mediate learning and memory.

Environmental and Experiential Effects

Animal and human studies have confirmed a lasting and substantial effect of experience and environmental conditions on a wide variety of learning tasks. For example, early handling of rodents appears to have a lasting, positive effect on cognitive performance. It has been suggested that the early experience enhances internal regulation of stress hormones and prevents at least some of the insult to the hippocampus and other structures that may occur across the life span. Other common manipulations used in environmental enrichment studies involve the provision of a changing array of objects to manipulate and explore within the home cage to stimulate cognitive and neurological activity. Positive effects of early exposure to an enriched environment are well documented in a variety of learning tasks; this results in significant changes within the brain structures implicated in cognition. Effects of environmental enrichment on mature animals are somewhat less well defined but are predominantly encouraging.

Long-term exposure to an enriched environment has been found to have substantial positive effects on a variety of learning tasks. Concurrent preservation of neuronal structure and function has been observed within the hippocampus and cortical areas as well. Greenough and associates described attenuating effects of a complex environment on cerebellar neuronal morphology in aged rats. Thus, primary structures involved in cognitive processes appear to be significantly altered by environmental conditions in both younger and older subjects. We have examined the

effects of modest, short-term environmental enrichment on acquisition of operant behavior in an appetitive task in aged rats. Access to a rotating series of simple cage toys for a relatively brief period of several weeks was sufficient to significantly diminish the delay in initial acquisition of operant responses by aging subjects.

While the data from both young and aging animals suggest a powerful effect of environmental condition on learning, the impact as noted in a relatively few studies involving humans has been less promising. Early enrichment has been found to have substantial positive effects, but the results of attempts to improve learning performance in aging humans by environmental conditions has been somewhat disappointing. Differences in the vast ability of the researcher to control the environment in animal studies, and considerably less ability to control the human environment, along with volition issues in human subjects may contribute to the apparent differences.

Prior recent learning experience may influence performance in classical and operant conditioning via the natural induction of learning-related LTP. Potentiation of hippocampal synaptic transmission occurs in most learning situations and has been shown to last for periods of weeks to months after training. Numerous studies have demonstrated the development of LTP during classical conditioning of the rabbit eyeblink. Similarly, we have noted that after aged (and younger) animals are operantly conditioned, synaptic function within the hippocampus is markedly enhanced; no differences in excitability were noted between age groups after training. Control data from untrained subjects indicated a significant reduction in excitability in the naive aging subjects. A subsequent evaluation of trained animals in spatial learning performance, which is normally affected by age, revealed no significant difference between age groups. Evaluation of synaptic function in untrained younger and aging subjects revealed age-related differences in the form of diminished reactivity within the aging subjects. Additional studies have observed that improved learning may occur as a consequence of prior training experience as well. This experiential effect is consistent with the 'use it or lose it' perspective of cognitive and neurological function, and provides an additional potential means of addressing age-related changes in cognition.

Pharmacological Effects

The elucidation of brain structures that mediate associative learning processes and that are significantly affected by aging allows researchers to attempt to ameliorate age-related deficits by pharmacological manipulation of targeted brain regions. In addition to providing a potential therapeutic tool, successful neurochemical intervention further delineates the probable elements underlying age-related decline in performance. NMDA receptors mediate the LTP seen in associative learning, are heavily distributed within the hippocampal region, and are substantially reduced as a consequence of normal aging. Since electrical induction of LTP facilitates simple learning, pharmacological enhancement of NMDA activity should improve learning performance in all age groups.

In classical conditioning, NMDA agonists appear to have a general enhancing effect (while antagonists have a deleterious effect) on acquisition. D-cycloserine (DCS), a potent NMDA agonist, has been shown to markedly improve acquisition in both younger and aging rabbits in a dose-dependent fashion, whereas dizocilpine maleate (MK801), an antagonist, has been shown to impair acquisition. In operant appetitive conditioning, we found that neither DCS nor MK801 had a significant effect on the number of days required by young adult rats to reach a training criterion. However, DCS delayed the extinction process and MK801 accelerated the extinction process in young adult rats. In more complex schedules of reinforcement, such as DRL and fixed interval schedules, NMDA antagonism has a disruptive effect on the performance of young adult rats. It is yet to be determined whether DCS would alleviate the delay in simple acquisition noted in aging rats.

Conclusion

The effects of aging on classical and operant conditioning in both animals and humans have been widely investigated. A pervasive deficit in the initial acquisition of learned behaviors has been noted to occur early in the life span of the subject and persists thereafter. Once this initial impairment is overcome, aged subjects tend to be as competent in the performance level achieved, maintenance, and resistance to extinction as their younger counterparts. The hippocampal formation and cerebellum appear to play prominent roles in both learning processes in general and the age-related decline in acquisition performance. Both structures show marked anatomical and functional changes as a consequence of age. Pharmacological enhancement of hippocampal and cerebellar functions, such as through the use of NMDA receptor agonists, can have a beneficial impact on learning performance. However, both structures also appear to be highly capable of reactive plasticity in response to environmental and experiential factors.

Consequently, in healthy aging subjects, a stimulating environment and persistent history of active learning experience may be the most effective and appropriate interventional strategy. However, the effects of environmental intervention appear to be limited by general health problems (i.e., metabolic or circulatory defects). A continuously active lifestyle (including both cognitive and physical aspects) may be an effective preventative and interventional mechanism. In disease conditions, such as Alzheimer's, classical conditioning appears to be a valuable tool to selectively detect early stage cases. In pathological states, pharmacological supplementation of neuronal function may be of significant benefit and could occur in conjunction with cognitive rehabilitation.

See also: Behavioral Genetics; Brain and Central Nervous System; Dementia: Alzheimer's; Learning.

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Consumer Behavior

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Glossary

Baby Boom Generation – The approximately 76 million people who were born between 1946 and 1964.

Decision Heuristics – Shortcuts or simplifying strategies for making decisions.

Gerontographic Segmentation – Segmentation of older consumers based on psychological, social, physiological, and lifestyle characteristics.

Marketing Mix – Usually product, price, promotion, and distribution.

Market Segment – Group of consumers with similar needs and wants.

Target Market – A specific market segment or segments that an organization attempts to reach with a marketing mix designed for the needs and wants of the segment(s).

Working Memory – The location where information is stored temporarily and is encoded for transmission into long-term storage.

Introduction

Consumer behavior encompasses mental and physical activities that consumers engage in when searching for, evaluating, purchasing, and using products and services. In the marketplace, consumers exchange their scarce resources (including money, time, and effort) for items of value. A consumer researcher studying how consumers buy long-term care insurance might investigate (1) the characteristics of consumers who buy this type of insurance (e.g., income, age, lifestyle), (2) where they buy it (e.g., from an agent vs. from an 800 number listed in an advertisement), (3) when they buy it (e.g., after a critical event such as a parent's illness or after seeing an ad), (4) how they buy it (e.g., comparing many policies vs. selecting the same one that a friend has), (5) why they buy it (e.g., fear of depleting life savings vs. desire for excellent care in old age), and (6) what happens after they buy it (e.g., satisfaction with the decision and the company).

Motivation for Studying Older Adults' Consumer Behavior

Until recently, business and marketing researchers virtually ignored the older market. Perhaps this neglect arose from inaccurate stereotypes about elderly consumers. However, more and more businesses, governmental agencies, and researchers recognize the importance of the rapidly growing older market. In 2005, there were about 35 million people over the age of 65; by 2010, this number is expected to reach 50 million. By the year 2020, one out of every six Americans will be 65 or older. In this article, we first discuss why businesses, policy makers, and researchers are interested in the growing older market, then we discuss consumer decision making, and finally we discuss how the aging process affects the consumer decision-making process.

Business

Not only is the size of the elderly population increasing, but the financial and health characteristics are also improving. For example, the AARP reported that from 1995 to 2005, Americans aged 50 and over have seen their economic status improve, when status is measured in terms of median inflation-adjusted income and household financial assets. Additionally, in the same time period, the proportion of family budgets available for discretionary items has increased for the 50 + population overall. Census data also suggest that over half the people 65 and over report no activity limitation.

The travel industry illustrates how businesses have started targeting older consumers. Many older travelers are attractive to the travel industry because they are wealthy, with high discretionary income, relatively low consumer debt, and abundant free time. Additionally, they tend to travel greater distances and for longer periods of time than their younger counterparts. Like the younger market, the older market is heterogeneous enough to warrant breaking into subsegments using gerontographic segmentation schemes. For example, the travel industry segments the over 55 market by motivations such as spending time with family, seeking intellectual and spiritual enrichment, meeting other people, and learning new things. Once the market is broken down into subsegments, travel agents, like other business decision makers, select target markets and then tailor the marketing mix to the needs and interests of each market segment.

Public Policy

As the size of the older market increases, increasing numbers of older adults are the targets of unscrupulous business activities. For example, current data suggest that about 34% of the victims of telemarketing fraud are elderly. White House Conferences on Aging and the Senate Special Aging Committee have also identified difficulties elderly people encounter when applying for credit, purchasing food, buying insurance or investments, using prescription drugs, selecting medical services, and using the Internet safely. Statistics cited at the March 2004 Senate Special Aging Committee hearing indicated that 59% of people aged 50 to 64 and 22% of those over 65 have become Internet users. Law enforcement has witnessed a corresponding growth in online fraud targeted toward older users. This fraud includes identify theft, 'phishing' schemes, in which criminals set up emails and websites designed to look like those of legitimate companies and financial institutions, non-delivery of merchandise, and investment fraud.

One possible remedy entails passing legislation to restrict the more unscrupulous business practices. For example, current legislation is being considered to better regulate Internet business practices. Another possible remedy includes increased consumer education efforts, which can not only increase knowledge about consumer rights, but also can prevent inadvertent participation in fraud. An AARP survey suggested that the problems older Americans face

from dishonest businesses are compounded by older adults' lack of knowledge about their rights as consumers. For example, older consumers (those over the age of 65) are much less likely than consumers under the age of 65 to know that you have several days to cancel purchases made from door-to-door salespeople (36% vs. 53%) and that consumers are not able to cancel purchases made by credit card over the telephone (19% vs. 28%).

Both business practitioners and public policy makers, then, are vitally interested in reaching older consumers. Consumer behavior researchers offer insight into how to achieve this through two main avenues: adapting theories of aging from other fields to the marketplace and adapting marketing theories and models (such as consumer decision making) to the elderly. These goals encompass a wide variety of research areas that we have only begun to study.

Theoretical

Theories and models which offer explanations for age differences in consumer behavior are useful to practitioners who would like to predict the behavior of future cohorts of elderly consumers. For example, a practitioner might ask the following question: "As the baby boom generation reaches retirement age, will their general consumption patterns change to be similar to those in the current over 65 market, or will their general consumption patterns remain unique to their cohort?" Answering this question is difficult, but developing theories about how aging affects consumers makes finding the answer easier.

Social aging theories, as applied in marketing, involve understanding how society assigns people to consumer roles across the life span. Consumer roles change as a person passes through different life stages. For example, entering retirement represents a major transition point when people move from one set of activities and social relationships to a new set of activities and social relationships. Businesses can respond to these changing needs. A travel agency might design group trips for older adults that present opportunities to meet new people with shared interests. Similarly, employment agencies might develop services for those one in three baby boomers who are thinking about starting a second career as they rapidly approach retirement. Additionally, one possible effect of retirement might be greater use of the mass media and the Internet during daytime hours to help counteract social isolation. Radio and television networks might develop programming to service this market segment. Social aging theories are useful because they highlight how consumer needs change as people move through different stages in the life course.

Cognitive theories of aging have contributed insights into all aspects of decision making. Cognition entails the mental processes that transform, reduce, elaborate, sort, and retrieve sensory input. One mechanism affecting cognition is working memory capacity. The capacity of working memory is limited in all adults, but the elderly may experience either a decline in the capacity or a slowing down of processing speed. Thus, older adults are not able to store as much information or process as much information as younger adults. Specifically, strategies for encoding information from sources such as advertisements and product labels may take much longer for the elderly to execute than younger adults. As they age, people may experience a decline in their explicit memory, a form of memory that allows us to retrieve pieces of information and their sources consciously (e.g., remembering an advertisement for a car manufacturer, when it was seen, and where it appeared). By understanding age-associated cognitive changes, businesses and public officials can design communication strategies.

Socioemotional selectivity theory hypothesizes that older adults, who perceive their time horizon as limited, place greater emphasis on emotionally meaningful goals (goals related to feelings, such as balancing emotional states) than on knowledge-related goals (goals related to new information acquisitions). This age-related shift in goals could influence the type of information people use to make decisions (affective knowledge versus other types of information), the type of information people recall, and their preference for dealing with familiar suppliers (e.g., a familiar car dealer).

Theories developed to understand aging processes help us understand consumer behavior of all age groups. For example, working memory limitations may affect younger consumers when they face tasks involving very demanding memory loads and fast rates of presentation – as is the case with telephone sales presentations. Although young adults use processing strategies efficiently, at some point, memory loads and time pressure may combine to interrupt the routines that adults typically use.

Dual Process Models of Consumer Decision Making

Generally, there are two routes consumers making decisions follow. In deliberative systematic decision making, consumers make slow, careful decisions. Consumers making such decisions generally pass through five stages: problem recognition, information search, alternative evaluation, purchase decision, and

postpurchase behavior. For example, a consumer buying a new home would generally use systematic decision making. However, in affective/experiential decision making, consumers make intuitive, automatic, and fast decisions. They may pass directly from problem recognition to purchase decision to the postpurchase phase. For example, a consumer deciding which movie to see might employ affective decision making. Individual characteristics, such as personality and information-processing ability, and external events, such as cultural values and exposure to advertising, influence which process consumers use.

Problem Recognition

Problem recognition is the first step toward making an actual purchase. Consumers recognize that their ideal situations differ from their actual situations. It can be as simple as noticing that the coffee is running low, or as complicated as realizing that life insurance is needed. Occasionally marketing itself can trigger problem recognition, such as when a salesperson points out the inferiority of a car without anti-lock brakes.

Information Search and Alternative Evaluation

After recognizing that problems exist, consumers begin to search for information about solutions to their problems. Search can be either internal, in which consumers scan their memory for previous experiences, or external, in which consumers consult a wide variety of informational sources, including advertising. Some would argue that marketing has the greatest capacity to affect consumer behavior during the information search stage.

A great number of factors affect how consumers search. For example, as perceived time pressure increases, search decreases. As knowledge increases, search may decrease. For example, a consumer may quickly search for the usual cereal brand, because she knows it meets her nutrition requirements. However, knowledge may lead to an increased amount of search, especially for non-routine decisions. For example, computer experts who are buying new computers will read more and speak longer with salespeople because they understand bytes, RAM, and processors. By searching, consumers learn about decision criteria and available alternatives. Generally a consumer weighs the perceived payoff from searching against the effort needed to search.

To evaluate alternatives, consumers may systematically combine information about each alternative on the important criteria. Alternatively, consumers may use heuristics to solve their purchase problems. One heuristic might be 'Select the first cereal that is low in sugar and high in fiber.' Such a simplifying rule makes the grocery shopping task easier, but means that the consumer does not consider all the available alternatives or all the available attributes.

When consumers have limited processing resources, they may rely on affective feelings to direct their choice process, rather than cognitions. For example, in one experiment, consumers with limited processing resources were more likely to choose a chocolate cake snack, an option that generates positive affect and negative cognitions about health, than to choose fruit salad, an option that generates negative affect and positive cognitions about health. In a different experiment, consumers who were in a good mood rated a new cookie as better than consumers who were in a bad mood, even though the mood was caused by an unrelated event. In both studies, consumers are quickly relying on affect, instead of cognition, to make choices and form judgments.

Purchase Decision

Consumers might make a brand decision before actually visiting the retail outlet. For example, before grocery shopping, the consumer might draw up a grocery list. Alternatively, the consumer might decide on a destination, such as a mall, and then once at the mall select a branded item such as a dress.

Postpurchase Behavior

Once consumers purchase products, they must decide how satisfied they are with their purchases. Often this involves anxiety or stress about the decision, called cognitive dissonance. Because this stress feels uncomfortable, consumers will often take steps to alleviate their dissonance. At this point, consumers may enter the search stage again, looking for information that confirms that they made the right decision. Many advertisers utilize advertising to help alleviate this cognitive dissonance. Additionally, some research considers how consumers dispose of products that they no longer need.

Age Differences in Consumer Decision Making: Empirical Evidence and Explanations

Although consumer decision-making research spans a broad range of topics, researchers studying age differences in consumer decision making have tended to focus on just a few topic areas. In this section and in **Table 1**, we review the empirical evidence for age differences in search for information, use of advertising information, alternative evaluation, and purchase decisions.

Table 1 Research on age differences in consumer decision making

Topic	*Reference*	*Method*	*Major findings*
Search for information	Lin and Lee (2004) *Financial Services Review* 13: 319–332	Survey	Older adults (OAs) consider fewer sources of information about investment decisions than younger adults (YAs)
	Lambert-Pandraud, Laurent, and Lapersonne (2005) *Journal of Marketing* 69: 97–113	Survey	OAs consider fewer brands, fewer dealers, and fewer models than YAs
	Cole and Balasubramanian (1993) *Journal of Consumer Research* 10: 417–431	Experiment field study	OAs search as much as YAs when the task is familiar; OAs search less when the task is unfamiliar
Advertising	Phillips and Stanton (2004) *Journal of Targeting Measurement and Analysis for Marketing* 13: 7–21	Commercial database with results of 5000 plus copy tests	YAs recall executional elements better than OAs, but OAs are more likely to be persuaded than YAs
	Fung and Carstensen (2003) *Journal of Personality and Social Psychology* 85: 163–178	Experiments	OAs learn more from ads that emphasize emotionally meaningful goals than from other types of ads, while YAs learn the same from all types of ads
	Cole and Houston (1987) *Journal of Marketing Research* 24: 55–63	Experiment	OAs learn less than YAs from TV and print advertising
	Gaeth and Heath (1987) *Journal of Consumer Research* 14: 43–54	Experiment	OAs are less able than YAs to process advertising claims
Alternative evaluation	Kolodinsky, Hogarth, and Hilgert (2004) *The International Journal of Bank Marketing* 22: 238–259	Survey of consumers by Federal Reserve Board	OAs are less likely to adopt phone banking and electronic banking than YAs
	Gilly and Zeithaml (1985) *Journal of Consumer Research* 12: 353–357	Survey	OAs are as likely as YAs to adopt a new technology when the relative advantage is clear
	Gwinner and Stephen (2001) *Psychology and Marketing* 10: 1031–1048	Survey	Cognitive age influences information-seeking behavior and new brand trial
	Reese and LaForge (1995) *Journal of Marketing Theory and Practice* 3: 37–49	Commercial database	Compared to other life cycle stages, older singles are more likely to report using disjunctive rules, and retired older couples are more likely to use conjunctive decision rules
Purchase and postpurchase decisions	Moschis, Curasi, and Bellinger (2004) *Journal of Consumer Marketing* 21: 123–133	Survey	Patronage motives of OAs are different from those of YAs
	Tepper (1994) *Journal of Consumer Research* 20: 503–519	Experiment	Consumers 50–54 are least likely to use senior discounts; consumers 65+ are most likely
	Price, Arnould, and Carsi (2000) *Journal of Consumer Research* 27(September): 179–200	Depth interviews	When discussing cherished possessions and their disposition, OAs express concerns about avoiding intrafamilial conflict, reducing uncertainty, and exercising control over the possessions

Search for Information

Older consumers search for different and often less information than younger consumers. For example, when making investment decisions, older consumers, compared to younger consumers, are more likely to use television media and are less likely to use the Internet for information about investments. In addition, older consumers spent less time searching for investment information than younger consumers. One survey of automobile buyers found that older consumers searched for fewer brands, dealers, and models than younger consumers.

Another study investigated age differences in search behavior in a supermarket setting and in a computer laboratory. Two observers watched consumers buying

cereal in a supermarket. Shoppers inspected very few packages before making a choice, so no age differences emerged in how much people searched. However, when an observer intercepted shoppers and asked them to purchase a cereal that met certain nutritional criteria, younger adults engaged in more search than older adults, who did not change how much they searched. In the laboratory, using a computer search program, older adults searched for less information about unfamiliar cereals than younger adults.

Whether or not age differences in search emerge may depend on task characteristics. Age differences in search may not emerge when consumers perform simple, routine tasks such as grocery shopping because not many people search very much in such situations. When engaging in familiar but complex tasks such as buying a new car, older adults may search less than younger adults because they use their years of shopping experience to design efficient search strategies. However, elderly consumers may restrict search when given a new search problem because of scarce information-processing resources. For example, older consumers with diminished working memory capacity may not easily store information about alternatives in memory. As a result, they may not search for as much information as younger consumers.

Use of Advertising Information

Although older consumers generally recall less information from advertisements than younger consumers, the size of these age differences often depends on the characteristics of the advertisements. For example, one analysis of a large commercial advertising research database found that age differences in recall varied across executional elements of print advertisements. In another study, older adults' recognition of information from advertisements with slogans that promote emotionally meaningful goals was significantly higher than their recognition of information from advertisements with different slogans (either none or those that promoted knowledge-related goals).

Another study found that age differences in recall and recognition varied across media. Younger adults recalled more from the television medium than they recalled from the print medium, but older adults did not realize the learning benefits of television; as a result, age differences were larger in the television medium.

Another studied advertising issue is whether or not there are age differences in the ability to judge truthfulness of claims in print advertising. Suppose an ad says "Brimstone tires will increase the safety of your winter driving." Then viewers are asked whether the statement 'Brimstone tires will increase the safety of your winter driving' has to be true. This procedure represents a test of a direct assertion. However, suppose the ad says "Have a safe winter. Drive on Brimstone tires." Then viewers are asked whether the statement 'Brimstone tires will increase the safety of your winter driving' has to be true. This procedure represents a test of a pragmatic implication. Apparently, there are no age differences when consumers judge statement truthfulness from memory. However, young adults are more likely to correctly judge the truthfulness of implied claims when the advertisements are available during assessment.

Alternative Evaluation

Consumer researchers have studied age differences in how consumers evaluate new products. For many years, marketing practitioners thought that older adults lagged behind younger adults in adopting new products and services. However, survey data suggest that this belief may be a negative stereotype, rather than reality. A 2004 study, which investigated how age and attitudinal characteristics affect consumers' willingness to adopt three types of new electronic banking products, reported that older consumers (over 65) were less likely than other age groups to adopt two of these. In another 1985 survey, younger and older consumers had different adoption rates for three of four new technologies.

What is interesting about both studies is that older consumers were as likely or more likely to have adopted some new technological products, including automatic bill payment and electronic funds transfer. Both sets of authors concluded that like other consumers, elderly consumers will purchase product innovations when the product possesses a clear benefit and meets a specific need.

How consumers choose different brands is another subtopic under alternative evaluation. Research supporting the idea that the older market is composed of subsegments finds that cognitive age, which is based on how old a person perceives him- or herself to be, affects brand choice more than chronological age. A different study found that how people select a brand of financial services depended on life stage, which is based on both age and lifestyle variables. When selecting financial services, older singles were more likely to report using a disjunctive decision strategy ('I chose the financial institution that I rated very good in at least one category') than other life stage groups, whereas retired older couples were most likely to report using conjunctive decision strategies ('I chose the financial institution that I did not rate poorly in any category').

Purchase Decisions

A study of patronage motives for consumers in the selection of food and grocery stores found that those 55 and over differed from those under 55 on the importance they attached to variables such as store location, availability of age-related discounts, availability of personnel to assist consumers, availability of special services, and recommendations by other people their age. These authors concluded that both membership in the identified four gerontographic segments and age were important in understanding patronage motives for grocery store selection.

Some self-report studies indicate that elderly adults say they favor retailers that offer senior citizen discounts, but other surveys show that older adults are reluctant to participate in such programs. A consumer behavior researcher conducted an experiment in order to determine whether or not older adults respond favorably to age-related discounts. In the experiment, consumers learned that a 10% discount was either a senior citizen discount offered to customers over a certain age or a privileged customer discount offered to special customers. Consumers' reactions to the discount varied by age. Respondents in the youngest age group (50–54) were the least likely to use a discount promoted with an age segmentation cue, and adults over the age of 65 were willing to use either of the 10% discounts. The middle age group (55–64) was willing to use the senior discount even though they believed that others would not give senior citizen discount users much respect.

This research resolves prior inconsistencies about consumers' reactions to senior citizens' discounts. Apparently, mature consumers (those in their 50s) are reluctant to accept the label of 'senior citizen,' but by the time consumers reach retirement age, they are willing to accept the label.

Postpurchase Decision Making

One study examined how older adults dispose of favorite possessions. Through depth interviews the researchers studied various aspects of disposition decisions, including precipitating events, emotions associated with decision, meaning of possessions, and tactics for disposing of possessions. Of these, precipitating events seemed most sensitive to age differences, but future research might make additional comparisons.

Summary

Generally, the existing decision-making literature suggests that elderly consumers differ from younger consumers in important ways at each stage of the decision-making process. At the information search stage, the presence of age differences in amount of search and in learning from advertising is not surprising because most of the consumer behavior research is based on extensive prior work in gerontology. At the alternative evaluation stage, a host of unresolved questions center on the decision rules and heuristics that consumers of different ages use when evaluating alternatives. Some processes may differ across age groups because older consumers, with fewer cognitive resources than younger consumers, may perceive higher cognitive costs for certain strategies than younger consumers. Other processes may not differ, when consumers can use familiar, well-practiced heuristics.

The marketing literature has contributed to knowledge by showing that differences found in laboratory research emerge in 'real world' settings. Future research might examine how the older consumer's considerable knowledge and experience moderates any age differences that emerge at each stage of the decision process. In addition, it is important to keep in mind that the older market is diverse and that different segments show these characteristics in differing amounts. Furthermore, even within a segment some consumer tasks may exacerbate or minimize these differences.

Improving Consumer Decision Making

We have described the decision-making process and how elderly adults differ from younger adults with respect to this process. Now we look at intervention programs designed to improve consumer decision making. Specifically, we consider decision aids, training programs, and education.

Improving Use of Information through Decision Aids

A series of studies investigated how age differences in selective attention might affect older adults' ability to use nutritional information contained on product labels. Literature from gerontology and psychology suggests that older adults are more susceptible to interference from the irrelevant components of a stimulus (or other environmental noise) than younger adults. In the experiments, subjects had to select a cereal that met certain criteria. Some subjects learned to circle the relevant information on the nutritional label with a red pen before they made a decision. The decision aid, then, was to highlight the relevant information. Both older and younger adults benefited from the perception aid. However, older consumers remained less able to make good nutritional choices than younger consumers even after being encouraged to focus on the relevant information. In another

experiment, the investigators boxed the relevant information and placed it in a separate location on the label. This time, subjects with moderate, but not severe, disembedding deficiencies were helped, but the field-independent subjects gained little from the aid. Given that the stated aim of nutritional labeling laws is to make nutritional information easy for all consumers to use, this study suggests that such information should be placed in the same spot on all labels.

A different group of investigators tried to aid use of nutritional information by encouraging older and younger adults to write information down as they acquired it from the computer. Using this decision aid, age differences in search intensity were greatly diminished.

Taken together, these two studies suggest that decision aids may successfully improve consumer decision making. Circling or writing down important information may especially help the elderly consumer focus on relevant information. Thus, in an environment where there is information overload, simple decision aids may help.

Improving Decision Making through Training and Education

Through experience, older consumers develop persuasion knowledge, or knowledge about persuasion tactics and methods of resisting persuasion attempts. As such, given their well-developed knowledge structures, older consumers should be able to resist persuasive efforts better than younger consumers. Training programs might increase older adults' ability to recruit persuasion knowledge to resist deceptive marketing practices. However, empirical work indicates that when cognitive capacity is constrained, younger consumers are less likely to recruit persuasion knowledge to resist a sales pitch. This finding raises several interesting questions: Do older adults possess well-developed knowledge structures about persuasion tactics? If not, education programs may enrich their knowledge structures. If so, under what circumstances do they utilize this knowledge structure to resist persuasion efforts? Can training programs improve the accessibility of this knowledge structure?

Regarding training programs, two investigators developed an interactive training program to reduce susceptibility to misleading advertising without increasing consumer suspicion of advertising claims. They found that although training reduced susceptibility to misleading statements in both older and younger consumer groups, it also reduced the younger adults' ability to discriminate between nonmisleading and misleading claims.

The track record for consumer education programs is mixed. Consider, as an example, the private, federal, and state agencies attempting to educate Americans regarding good health practices. These agencies use the mass media as an integral part of most health promotion campaigns. Survey research shows that older adults are interested in maintaining or improving their health. However, many older adults have limited knowledge regarding the relationship between certain lifestyle behaviors and disease incidence. For example, government-sponsored surveys suggest that consumers do not understand why or how controllable risks such as diet, exercise, and weight control are important factors in disease prevention. Thus, there is a need for additional research identifying how to more effectively educate older consumers about health and other topics.

Summary

In summary, efforts to eliminate age differences in decision making have not been entirely successful in equating older adults' performance with that of younger adults. Instead, decision aids, training, and education often help all age groups equally.

To develop a decision aid that differentially benefits the older consumer, consumer researchers must first closely analyze the consumer's task. They then need to identify exactly where in task performance age differences arise. For example, do age differences emerge at the information acquisition stage or at the alternative evaluation stage? Furthermore, the consumer behavior researcher needs a model about why these age differences emerge. Perhaps age differences at the information acquisition stage arise because of working memory differences. Once researchers understand the source of age differences, they can design effective aids.

However, the consumer behavior researcher needs to evaluate the consequences of 'aiding' decision making. For example, when researchers trained subjects to discriminate between directly asserted and implied claims, they worried about increasing younger subjects' skepticism of advertising. Similarly, an advertiser targeting older adults may increase learning in this audience by increasing the number of message repetitions. However, if younger adults are also part of the target market, increased message repetitions may irritate and alienate these consumers.

In addition, the consumer behavior researcher needs to think about whether the aid is managerially relevant. For example, two researchers suggested that consumers should highlight relevant information

before making a decision. However, it is not realistic to recommend that consumers take pens into the supermarket to highlight relevant information on product packages. Retailers would be unhappy if consumers put back on the shelf marked packages that did not meet the consumers' needs.

Future Research Directions and Concluding Comments

Over the life course, consumers build up a repertoire of strategies for solving diverse consumption problems. These problems include routine tasks such as buying cereal at the grocery store and complex tasks such as buying long-term care insurance. Both the consumption problems and the strategies people use to solve the problems evolve over time to reflect a person's changing life experiences and abilities. Decision aids, training, and modified marketing stimuli can make it easier for consumers to use different strategies by reducing the cognitive effort required to execute a particular strategy.

There are a number of unanswered questions about how older consumers adapt their decision-making strategies to changing cognitive abilities, social roles, and task and context demands. Preliminary evidence suggests that the situations in which older consumers are likely to run into difficulties because of changed cognitive abilities are typically new situations with new products or services. Older adults may, for example, encounter difficulties learning new information through advertising; similarly, they may run into problems using new product information presented on a nutritional label. In new situations, older consumers may limit search for information, rely on previously learned decision strategies, and/or resist innovations until the benefits are clear.

Because there is considerable heterogeneity in the over 65 market, it is important to bear in mind that age-related changes in cognitive ability are not the same for everyone and in fact may not occur for everyone. An individual's health history and lifestyle may attenuate the timing and size of changes. Much of the consumer behavior literature points out memory deficiencies in older adults in comparison with younger adults. However, the magnitude of memory deficits appears to vary with task conditions of information processing and how information is placed into or recovered from memory.

Studying the consumer behavior of older Americans has never been more important than it is now in the early twenty-first century. With the impending maturity of the baby boom generation, the size of the elderly consumer market poses a force that businesses, public policy makers, and academic researchers can no longer ignore. The older consumer behaves in ways that are inherently different than the ways a younger consumer does. We have briefly discussed many of these differences in this article. Marketing strategies aimed at affecting older consumers' behavior must then be formulated specifically for the older market.

See also: Decision Making and Everyday Problem Solving; Information Processing/Cognition; Memory.

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Creativity

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Glossary

Career Age – The number of years a creative individual has been active in a given domain (as contrasted with chronological age).

Cumulative Advantage – The phenomenon in which creators who are initially successful gain advantages that help them become even more successful compared to those who are less successful at the outset.

Divergent Thinking – The mental capacity for generating numerous, varied, or original responses to a given conceptual stimulus.

Equal-Odds Rule – The principle that quality of output (creativity) is a positive and constant function of quantity of output (productivity).

Old-Age Style – The distinctive mode of expression that characterizes the final works of great artists.

Swan Song Phenomenon – The tendency for composers to produce highly distinctive musical masterpieces in the closing years of their life.

Introduction

Creativity is an elusive concept that is not easily defined. The only statement about creativity that can be made with absolute confidence is that creativity has something to do with the production of creative ideas. An idea is said to be creative if it fulfills two conditions. First, the idea must be original in the sense of statistical rarity. Ideas that emerge from only one individual are more original than those that arise in the minds of many individuals. Many people have held down a beach blanket with a shoe, but only one person has revolutionized physics by proposing the general theory of relativity. Second, the idea must be adaptive in some meaningful way. For instance, it must solve an important problem or accomplish a significant task. Without this second requirement, one could not distinguish the bizarre mental ramblings of a psychotic from the breakthrough ideas of a scientific genius. Hence, creative ideas are simultaneously original and adaptive.

When we try to get more specific, however, the consensus disappears. Different researchers will have contrary conceptions of what creativity entails. There are at least three main viewpoints:

1. Creativity is a mental process, or a set of mental processes, that generates creative ideas. These cognitive operations might include insight, intuition, and imagination. This is the preferred definition of cognitive psychologists who study problem solving in laboratory experiments.
2. Creativity is a characteristic of concrete products, such as paintings, poems, or inventions. Those products that satisfy certain standards – such as novelty, elegance, beauty, and technical virtuosity – are called creative. This is the perspective adopted in theoretical and empirical aesthetics.
3. Creativity is a special personality trait, or cluster of traits, in which individuals may vary. For example, individuals who exhibit sufficient intelligence, ambition, determination, independence, and originality may be identified as creative. This is the definition adopted by personality psychologists who examine the traits that distinguish creative persons from everyday populations.

Hence, creativity may be examined as a process, a product, or a person. Despite this conceptual divergence, these three perspectives can overlap and converge in various forms. For instance, researchers might study individual differences in cognitive styles – or preferred modes of information processing. This variation may then correlate with the production of creative ideas. Other investigators may examine individual differences in the output of creative products. Those persons who are the most prolific may be said to be the most creative, according to this criterion. Thus, there exists a tremendous variety of ways that creativity can be examined in the behavioral sciences.

From the standpoint of gerontology, the most crucial issue has always been the relationship between creativity and aging. Does creativity necessarily decline with age? Is the age decrement such that we cannot expect creativity from individuals well advanced in years? What circumstances enable a person to maintain high levels of creativity toward the very end of life? These questions are important for both practical and theoretical reasons. On the practical side, a negative relationship between creativity and old age would provide a strong case for compulsory retirement. At least this argument could apply to those who are employed in positions in which creativity

is essential to effective performance. Professors at research universities and scientists at industrial laboratories are obvious examples. On the theoretical side, furthermore, an age decrement in creativity would have important consequences for our understanding of the aging process. Indeed, the supposed creative decline in later years has often been taken as a sign of intellectual impairments in the final decades of life. If this commonplace conception were shown to be very much mistaken, we would have to draw very different conclusions about the nature of aging.

Because there are multiple definitions of creativity, the relationship between aging and creativity can be examined in more than one way. Actually, researchers have tended to attack the problem from just two different angles. On the one hand, some investigators have defined creativity in terms of performance on measures of the mental processes most relevant to the production of creative ideas. These psychometric instruments are often referred to as 'creativity tests.' On the other hand, other investigators have preferred a more behavioral definition, using counts of creative products as indicators of underlying creativity. The creative achievements in these longitudinal tabulations may include paintings, poems, compositions, patents, books, journal articles, or other discrete items. These alternative research strategies do not always lead to identical conclusions.

Psychometric Assessments

A large number of psychometric instruments exist that purport to assess creativity. However, most investigators have relied on those creativity tests that evaluate a person's capacity for 'divergent thinking.' Measures of divergent thinking examine whether a person can produce a large number of alternative and novel responses to test stimuli. There are several such instruments, each concentrating on a particular process (fluency, flexibility, originality, etc.) or medium (verbal versus visual). Whatever the details, studies using these divergent thinking tests have often found that creativity tends to exhibit a roughly inverted U function with age. That is, the scores may peak somewhere in the 30s or 40s and thereafter decline. Judging from these psychometric inquiries, creativity shows a noticeable and sometimes quite pronounced decrement in the latter half of life. The aging process appears to be antithetical to the demonstration of creative activity.

Nevertheless, these psychometric findings must be interpreted with great caution. These results may not necessarily provide conclusive proof that creativity must decline after an individual reaches middle age. There are three principal difficulties:

1. Most of these psychometric studies rely exclusively on cross-sectional rather than longitudinal data. Instead of actually looking at how test performance changes as an individual gets older, most investigations merely compare the test scores of individuals at different ages. The latter approach is adopted simply for convenience. It obviously takes more time to examine the same subjects for several years in order to gauge the changes more directly. Yet in the absence of a truly longitudinal analysis, the findings can be extremely misleading. The effects of age can be confounded with the effects of cohort. It is possible, for example, that the older persons in a sample came from a generation that attended schools with quite different educational philosophies than those that predominated when the younger persons in the study were educated. These differences alone could account for any observed contrasts in test performance in cross-sectional studies. Hence, it is significant that those few investigations that employ a longitudinal design usually report smaller declines in creativity than normally seen in cross-sectional research.

2. The form of the age curve depends greatly on the specific tests used. It must be emphasized that divergent thinking measures represent only one possible approach to the assessment of creativity. Consequently, different longitudinal trends can be obtained when alternative psychometric instruments are used. For instance, tests that evaluate problem-solving skills in more everyday situations can actually produce scores that increase with age. In addition, measures that impose strict time limits during test administration tend to show greater age decrements than those instruments that are untimed. This difference reflects the fact that the speed of thought processes tends to decline in the later years of life. Timed tests thus put older subjects at a comparative disadvantage.

3. Many experts in the area of creativity research seriously question the validity of all so-called creativity tests. Validation studies usually show that such tests display rather modest correlations with direct measures of creative behavior. The main problem is that most of these psychometric measures assess generic mental processes and cognitive styles. Yet investigators have come to realize that creativity is, for the most part, domain specific. For instance, an individual might be highly creative in music but exhibit no creativity whatsoever in literature. Part of the reason for this differentiation is that creativity in any field requires the acquisition of a tremendous amount of domain-specific knowledge and skills.

Creative individuals must usually devote approximately 10 years to intensive study and training before they have the expertise necessary for the production of ideas that are both original and adaptive. This essential requirement is completely overlooked by tests that assess mental processes or cognitive styles in domains of general information.

These three difficulties suggest that it may prove more fruitful to adopt an alternative strategy. If we wish to learn how creativity changes with age, it might be best to scrutinize how the output of creative products changes during the course of a creator's career. Such inquiries would be inherently longitudinal in design, and the indicators of creativity would enjoy the most validity. After all, the production of creative ideas is the primary criterion against which we must evaluate any measure of creativity.

Productivity Measurements

The scientific study of the relation between age and creative productivity began in 1835, and thus it represents one of the oldest topics in gerontological research. The classic investigations are those conducted by Harvey C. Lehman, especially as summarized in his book *Age and Achievement*, in which he examined the fluctuations in creative output in a wide range of disciplines in the arts, sciences, and humanities. His data show a consistent tendency for creative productivity to follow an approximately inverted-U function with age. Creativity again rose to a peak somewhere in the 30s or 40s, and then progressively declined. The age decrement was very similar to what is observed in performance on the psychometric measures.

Unfortunately, Lehman's work suffered from many methodological deficiencies that rendered his results often ambiguous. These deficiencies caused many behavioral scientists to question the validity of his conclusions. Three problems were especially serious:

1. Lehman's tabulations focused on those products that were the most successful or influential. The total output of works was largely ignored. Critics of his research objected to the value judgment implicit in this methodological decision. The critics argued that a fairer gauge of creativity would require a count of the total output, regardless of whether the product attains acclaim or earns appreciation. When this alternative strategy was taken, productivity in the later years of life seemed more substantial than Lehman's statistics appeared to indicate.
2. Lehman did not make any correction for changes in the number of persons active within a creative discipline. There has been a tendency for this number to increase, sometimes quite dramatically. For instance, the number of scientists has been growing exponentially. As a consequence, the older a creator gets, the more other individuals will be active in the same creative domain. That tendency is tantamount to stating that as creative individuals age, they must face increasingly more competitors. Concert halls can perform only so many compositions, art galleries can exhibit only so many pieces, and journals can publish only so many articles. This puts each creator at an ever-growing disadvantage as they age.
3. Lehman's longitudinal tabulations often failed to introduce corrections for individual differences in life span. Counts of the number of creative products emerging at different ages will automatically show a decline in output if these counts are summed across large numbers of creative individuals, because those creators who die at younger ages will be prevented from contributing works at later ages. There are fewer creative products at the hands of 80-year-olds than 40-year-olds in part because octogenarians are relatively rare. Accordingly, those statistics that fail to adjust for this artifact will exaggerate the age decrement in the advanced years.

Fortunately, more recent research has taken advantage of more sophisticated methods to take care of these and other complaints. At the same time, these modern investigations have verified Lehman's central conclusion: the output of creative products tends to first increase with age until a peak is reached, after which productivity declines. The peak may occur a little later in life, and the post-peak decline may be less pronounced, but an age decrement occurs nonetheless. Even so, this same research also suggests that the prospects for creativity in the later years are not as dismal as they first appeared. The relevant findings concern (1) the magnitude of the age decrement, (2) contrasts across creative domains, (3) individual differences in lifetime output, (4) the contrast between career and chronological age, (5) extraneous influences on productivity, (6) the equal-odds rule, and (7) qualitative transformations in creativity.

Magnitude of the Age Decrement

Even though an age decrement is commonly observed, the size of this decrease is not as substantial as was often thought. Certainly the predicted level of creative productivity rarely drops to zero. In fact, output in the last decade of life can compare quite favorably to other decades of a creative career. For instance, persons in their 70s will usually be more productive than the same persons were in their 20s.

Moreover, this late-life productivity will look respectable even when contrasted with the career peak, when the output rate reaches the maximum. In the typical case, individuals in their 70s will be producing ideas at a pace only 50% below what they accomplished during the high point of their careers. It is trivial to debate whether this percentage means that the creative mind is half empty or half full after it enters the traditional retirement age. The conclusion remains that creative individuals do not necessarily 'dry up' or 'run out of steam.'

This fact alone should help us understand how it is possible for an impressive number of creative achievements to come from individuals who are well advanced in years. To offer some illustrations: Cervantes completed the second part of *Don Quixote* at age 68; Franklin invented bifocal lenses when he was 78 years old; Humboldt wrote his *Cosmos* when he was between 76 and 89 years of age; and Goethe finished the second part of *Faust* when he was in his early 80s. Perhaps the most remarkable example, however, is the case of Henri Chevreul. After a distinguished career as a chemist, Chevreul switched fields in his 90s to become a pioneer in gerontological research. His last publication appeared just a year before his death at age 103.

Contrasts across Creative Domains

Any consideration of the age decrement cannot ignore the considerable variation that occurs across domains of creative activity. The specific shape of the age curve, including the location of the peak and the magnitude of the post-peak drop, varies according to the discipline in which the creativity takes place. In some fields the peak will appear much later in life, sometimes around the 50s or 60s. Moreover, the decline will be very gradual, even imperceptible. Accordingly, octogenarians will be as productive as they were when they were in their supposed prime. This longitudinal pattern tends to hold for philosophy, history, and various forms of scholarship. For example, Kant published his first philosophical masterpiece, the *Critique of Pure Reason*, when he was 57, and his last notable contribution, the *Critique of Judgment*, when he was 66.

Of course, in other fields the age decrement will be accentuated. The career peak might appear in the late 20s or early 30s, and the post-peak decline may be almost precipitous. Such age curves tend to be seen in the output of lyric poetry, abstract mathematics, and theoretical physics. Nonetheless, the picture of late-life creativity is not totally grim. In the worse-case scenario, productivity in the 70s will fall to around 5% of the output rate attained at the career optimum. Thus, creativity is only slowed, not stopped. Nothing prevents individuals in one of these disciplines from coming out with a masterpiece in the final years. Tennyson was still producing notable poems in his 80s, and the last volume of Laplace's *Celestial Mechanics* appeared when he was in his 70s.

Individual Differences in Lifetime Output

There exists extraordinary variation in the lifetime output of various creative individuals. In fact, the distribution of total productivity is much more varied than the distribution of most physical and psychological traits, such as height or intelligence. Typically, the most productive creators in any field are at least 100 times more prolific than their least productive colleagues. So extreme is this contrast that the individuals who are in the top 10% in total output tend to account for about half of all the creative products in a particular domain. For example, only 16 composers account for half of the music regularly performed in the classical repertoire.

The productive elite attain this prodigious output in three ways. First, they tend to launch their careers earlier than normal, often in their late teens or early 20s. Second, they tend to maintain high annual output rates throughout their career, often publishing at two, three, or four times the rate of their less-distinguished colleagues. Third, they tend to continue their prolific output much later in life, most often letting death decide when their careers shall end. These last two components are especially crucial to understanding late-life creativity. Individual differences in creative productivity are so substantial that this variation will largely negate the impact of the age decrement when making comparisons across creators. Hence, highly prolific contributors in their 70s and 80s often display more creative productivity than much less prolific contributors who are active at their career peaks. Indeed, a Nobel prize-winning scientist will make more contributions after age 60 than most scientists make during their entire careers.

Career Age versus Chronological Age

It is a common mistake to conceive of the age curves as expressing creative productivity as a function of chronological age. Almost all of the tables and figures published over the past 150 years take this point of view. Along the horizontal axis of the typical graph, the researcher will usually mark off consecutive decades or half-decades according to age since birth (e.g., 20s, 30s, 40s, 50s). The investigator then counts the number of creative products falling within each time interval. This manner of presenting and analyzing the data is straightforward, but terribly

misleading. The curves expressing the changes in creative output across the life span are not strictly a function of chronological age, but rather of career age. What matters most is how long the individual has been engaged in a given creative enterprise. Hence, to be precise we should not say that an individual peaks at age 40, but rather that the peak is attained about 15 years into a career.

Admittedly, if we are counting creative contributions across a large number of individuals, the distinction between chronological and career age will make little difference. If the average person launches his or her career at age 25, then the average person will attain the optimum at age 40. Furthermore, chronological and career age will correlate very highly with each other. This strong association appears because people usually enter and leave the educational system at about the same ages anyway. Consequently, most beginning creators in a particular field will be in about the same cohort. Nevertheless, circumstances do arise in which the correspondence between chronological and career age breaks down. Some individuals might be 'late bloomers' who did not discover their true calling until they were more advanced in years. Some of these persons may have undergone mid-life career changes, perhaps even going to college as 'reentry students.'

Whatever the causes, those who begin their careers later in life will tend to have age curves that are displaced proportionally later as well. If the peak normally comes 15 years after the career onset, and the person does not get started until age 40, then the optimum will appear around age 55 rather than age 40. In addition, the impact of the age decrement would also not be felt until much later in life. The late starter may have to reach the 90th year of life before he or she showed any clear signs of serious decline.

The career of the Austrian composer Anton Bruckner illustrates this possible outcome. Bruckner spent the first part of his life as an obscure and provincial creator of church music. However, an encounter with the operas of Richard Wagner inspired him to become a symphonic composer with a similar sonic landscape. He therefore did not create his first symphony, a student piece given number 'OO,' until he was 39 years old, and he was 50 before his first masterpiece emerged from his pen. Two more successful symphonies appeared when he was 59 and 60 years of age. He died at age 70, before he could write the concluding movement to his last symphony. Yet that piece is still considered a masterwork. Because Bruckner's entire career was shifted over about 20 years, he was in his prime at an age when many other composers were well past theirs.

Extraneous Influences on Productivity

A large proportion of the decline in output in the last half of life is by no means inevitable. Rather, much of any age decrement can be attributed to extraneous factors. To the extent that these detrimental influences can be overcome, creative productivity can often continue at higher levels than those predicted by the usual age curves. For instance, as a career advances, creative individuals frequently find themselves increasingly engaged in activities that take them away from the studio, laboratory, or writing desk. In academic and industrial settings, these activities often entail time-consuming and stressful administrative responsibilities. Consistent with this adverse impact is the recurrent finding that creative persons will often experience an upsurge in productivity upon retirement. This resuscitation is especially likely in those domains in which knowledge or skill does not quickly become obsolete.

Perhaps the most obvious external constraint on productivity in the later years is physical health. Creative individuals, like everyone else, can suffer from debilitating illnesses in old age. Indeed, some creators have had to make heroic efforts to maintain any level of productivity at all. Johann Sebastian Bach was eventually obliged to compose his works by laborious dictation due to blindness; Matisse attached crayons to bamboo poles so that he could continue to create art from his wheelchair. Hence, any advances in medicine that lengthen the number of years of sound health will probably prolong and intensify the amount of creativity seen in the closing decades of life.

In contrast, certain environments can operate to sustain creativity well into old age. In the sciences, for example, those individuals who are embedded in a rich disciplinary network of colleagues and students tend to display much longer creative careers. This positive influence evidently operates by stimulating the scientists so that they can rejuvenate their creative potential. Likewise, those individuals who maintain a high level of intellectual activity, and who remain open to outside influences, will be able to keep their creative productivity at higher levels. This is one reason that the greatest artists often display multiple periods, each identified with a distinct style. Once these creators have exhausted one aesthetic framework, they will move on to another, and thereby refresh their creativity.

A fascinating illustration is the composer Stravinsky, who went through several musical styles over the course of his long career. At 70 years of age he quite unexpectedly revitalized his creativity by adopting a compositional style that he had hitherto ignored, the

twelve-tone technique of Schoenberg. This dramatic change permitted him to extend his creative life by another 10 years.

Equal-Odds Rule

Earlier it was noted that Lehman's studies were criticized for counting only successful works, while ignoring the often much larger output of unsuccessful products. The critics believed that if total output is examined, the outlook for late-life creativity would appear more optimistic. That is, productivity may remain high in the final years of life even if that productivity does not have an impact on contemporaries or posterity. One problem with this argument harks back to the very definition of creativity. A creative product is an entity that is deemed original and adaptive by other individuals. If an individual continues to produce unoriginal and ineffective works toward the end of his or her career, that does not mean that the person is still being creative. Hence, on analytical grounds, this argument has no relevance to the question of the relation between age and creative productivity.

Yet there is a more important point: The preceding argument assumed that the age curves for total output were different than those for just creative production. Presumably the post-peak decline is less drastic when all potential contributions are tabulated, regardless of merit. Nonetheless, earlier studies making this contention did not use the most appropriate methods. In fact, more recent analyses simply do not support this conclusion. The relation between age and productivity is essentially the same whether we count total output, successful output, or unsuccessful output. The peak occurs at about the same place during the course of the career, and the post-peak decrements are comparable. The ups and downs in the appearance of major products parallel those for minor products. Quality of output is strongly associated with quantity of output.

This concordance might lead to more pessimism about the prospects for creativity in the later years. But such pessimism is unjustified if the longitudinal data are examined from a different angle. The first step is to calculate the ratio of successful works to the total output produced in consecutive age periods. This yields a 'quality ratio' or 'hit rate.' To illustrate, for a sample of scientists this ratio would consist of the proportion of frequently cited articles relative to total articles produced during each age period. The next step is to see how this quality ratio changes as a creative individual gets older. The answer is straightforward: the ratio fluctuates randomly throughout the career. There are good years and bad years, but there is no consistent tendency for the hit rate to either increase or decrease, or display some curvilinear form.

Therefore, the older members of a creative domain boast the same quality ratio as their younger colleagues. This equal-odds rule has obvious implications for any discussion of the connection between age and creativity. Although these creative elders may be generating fewer masterpieces in their last years, they are also producing fewer neglected pieces. Each product has the same chance of success no matter how old the creator was at the time of production. So if creativity is gauged in terms of success rate, there is no rationale for speaking of an age decrement at all. The equal-odds rule thus advises everyone to judge each potential contribution on its merits, for age has no value as a predictor of creative accomplishment at this level.

Qualitative Transformations

One obvious limitation of simply counting creative products per age period is that the procedure implicitly treats all works as virtually identical. This hidden assumption is patently invalid. Clearly, an epic poem should get more credit than a sonnet, while a monograph should earn more points than a research note. The standard solution to this problem is to assign differential weights to the longitudinal tabulations. For example, musical compositions might be weighted according to the amount of thematic material they contain, the complexity of instrumentation, the number and type of movements, and playing time. This would make Beethoven's *Missa Solemnis* count more than his piano bagatelle *Für Elise*.

What makes the implementation of this solution especially urgent is that individuals tend to change their preferred mode of creative expression as their careers advance. A poet might begin with brief lyrics before attempting more ambitious narrative and epic forms; a scientist might start with journal articles and then write increasingly more books and monographs. Because the number of creative ideas found in each creative product thus increases over time, the output of titles will decrease faster than the production of ideas. The weighting procedures allow us to compensate for this crucial shift of growing creative maturity.

However, this methodological improvement ignores another qualitative change that is even more profound. As creators get older, they may grapple with more difficult themes and issues, and thereby make the content of their works more profound, and even devise forms much more rich. For instance, as authors age, their juvenile preoccupations with love

won and lost tend to be replaced with deeper ruminations on the meaning of life, on the place of human existence in the larger scheme of things. By waxing philosophical, creative individuals will often try to say more with less, to concentrate an intense amount of significance within strikingly elegant expression. These life span transitions require a more complex approach to the measurement of creativity. Even weighted counts will not capture the amount of creativity that may be going into each piece.

This point becomes especially urgent when we consider one final empirical finding: creators entering their last years often dramatically alter the approach they take to their creative activities. For instance, visual artists in their concluding years may exhibit a sudden shift toward what has been called the 'old-age style.' Similarly, composers will frequently display the 'swan song phenomenon.' Rather than betray a decline in creative power, these works often serve as last artistic testaments. Practically a creator's entire life and career is summarized within a single, often brief, but highly concentrated masterpiece that serves as his or her career's most worthy capstone. It is as if the greatest creative personalities wish to end it all with a bang, not a whimper. The very fact that an old master can still succeed in such an awesome task is ample testimony to the respectable creative powers that can yet remain in advanced old age.

Theoretical Interpretations

So far the focus has been on the empirical findings that describe the linkage between creativity and aging. Behavioral scientists have proposed a large number of theoretical accounts as well. These theories vary greatly in how well they explain the available data. They also differ with respect to their implications for creativity in the later part of life. These diverse theoretical frameworks fall into four broad categories: psychobiological, sociological, economic, and psychological.

Psychobiological Theories

Creativity obviously takes place in the human brain. Therefore, any biological process that impairs brain function as the body ages will naturally have a similarly negative impact on creative thought. For example, as people get older, reaction time usually tends to increase, as the general rate of information processing gradually slows down. If creativity is assessed by time tests, this neurological shift will necessarily cause inferior performance. Older individuals will simply generate fewer responses in a given unit of time. Hence, only on untimed tests can this inherent disadvantage be minimized. Of course, here we are referring merely to the quantity of ideas produced over a certain period. The quality of those ideas may not necessarily diminish just because the rate of output slows down. Indeed, the equal-odds rule shows that the ratio of good to bad ideas stays more or less constant throughout the life span.

Nevertheless, biological changes may affect the intellect in more subtle ways. Work on IQ tests has established the important distinction between crystallized and fluid intelligence. Whereas the former concerns relatively permanent knowledge, such as a person's active vocabulary, the latter concerns more flexible skills, such as problem-solving ability. For reasons not completely understood, these two types of intelligence have different trajectories across the life span. Crystallized intelligence will often steadily increase, with a relatively minimal age decrement toward the end, whereas fluid intelligence will normally decline somewhat rapidly in the later years. In fact, the divergent thinking tests discussed earlier may be viewed as measures of fluid intelligence, and their age trends follow the same course. This contrast is important because different kinds of creativity may require a distinctive mix of crystallized and fluid intelligence. The nature of this mix may then decide where the career peak tends to be for a particular field. The differences between mathematicians and geologists or between poets and novelists may be partly explained by this principle.

Even so, psychobiological explanations cannot account for many crucial features of longitudinal changes in creativity. Most conspicuous is the finding that creative productivity is principally a function of career age. By comparison, any psychobiological account must be expressed in terms of chronological age. Consequently, it is difficult to use this perspective to comprehend those individuals who enter a creative enterprise later in life, yet still manage to display the expected career trajectories. Perhaps the best conclusion to draw is that various biological factors operate mostly as extraneous influences. Their main effect on late bloomers may be to depress the height of the career peak and make steeper the slope of the post-peak decline. Meanwhile, the specific shape of the age curve will be largely dictated by other factors that have nothing to do with biology.

Sociological Theories

Sociologists adopt a totally different approach to explicating how creativity changes across the life span. Their tendency is to concentrate on objective creative behavior, as gauged by the output of actual products. This productivity is then seen to be largely if not

entirely the function of the prevailing reward structures of a discipline. These structures reinforce certain forms of creative output while discouraging other forms. Output is maintained across the life span when the social rewards for continued productivity are maintained throughout the career. On the other hand, productivity will diminish and disappear when the disciplinary reinforcements are no longer forthcoming.

This explanatory position is best seen in the principle of 'accumulative advantage.' According to this principle, creative individuals live in a very competitive world in which many are called but few are chosen. Not all papers submitted to professional journals will be accepted for publication; only a subset of the art works submitted to a show will be selected by the jury for exhibition. Those who have the fortune to achieve success early will have higher odds of attaining further successes, whereas those who experience the misfortune of early rejection will be more prone to endure further failure. Those in the first group are thereby encouraged to increase their productivity, while those in the second group will suffer discouragement, and eventually drop out of the race. This difference is accelerated because the initially successful will obtain access to social support – such as paid positions, laboratories, studios, contracts, fellowships, and grants – that will be withheld from those who have not yet proven themselves. The upshot is that the rich get richer and the poor get poorer.

The principle of accumulative advantage can explain many of the details of career trajectories. For instance, those individuals who are successful earlier will obtain the resources that will permit them to maintain their productivity at a higher rate and to continue their output until later in their career. In contrast, those less lucky will never become very prolific, and will end their productive careers earlier. This pattern closely approximates what is actually observed. A remarkable feature of this explanation is that it makes no assumptions whatsoever about individual differences in creativity. Even if all individuals entering the contest are roughly equal in native ability, they will eventually stratify according to the length and productivity of their careers. Moreover, persons who are no longer productive in the later years cannot be blamed for their fate. They are simply those who got off on the wrong foot at the very outset of their careers. If they had accumulated the same external resources as their most successful colleagues, they too would be just as prolific in old age.

Although the sociological account has many attractive aspects, it also suffers from numerous explanatory inadequacies. For example, it does not do a very good job of explaining the appearance of creative late bloomers. More seriously, it has problems with accounting for interdisciplinary contrasts in the career trajectories. Why do mathematicians peak early while geologists peak later? In addition, it cannot handle the finer details of individual variation in the career course. For instance, research has shown that the most prolific creators in a discipline attain their productive peaks at the same career age as their less prolific colleagues. The principle of accumulative advantage, in contrast, predicts that the former will peak later than the latter. Hence, the sociological framework may at best capture only a portion of the process underlying age changes in creative output.

Economic Theories

Economists have advanced an interpretation that has a certain affinity with that put forward by sociologists. They also posit that creativity is a behavior maintained by extrinsic incentives. Yet the economists focus more on the individual rather than on the reward structures of a creative domain. Economists begin by assuming that human beings are rational creatures who try to maximize the benefits they receive in life while minimizing the costs. Hence, individuals are always calculating 'cost/benefit ratios' or 'utility functions' in order to decide on a proper course of action. This calculation process becomes complex when a person has to examine the tradeoff between short-term costs and the corresponding long-term benefits. A classic example is education, which consumes much time and money in the short run, but helps ensure a comfortable standard of living in the long run.

Creative individuals face a similar choice. Creativity, according to the economists, requires considerable investment in 'human capital.' That is, creative individuals must devote much time, energy, and expense to mastering the knowledge and techniques of a field before they can generate a creative product. Yet only the products themselves bring benefits in promotions, prizes, and pay raises. Furthermore, creative individuals must continually reinvest their resources in order to maintain productivity throughout their career. Otherwise their expertise will become obsolete, and they will correspondingly fall behind the leading edge or latest fashion. For a person just starting out in a career, the short-term costs of this investment will pay great dividends in the long term. Yet for a person already well advanced in years, the current losses may outweigh the expected gains. For one thing, death may end the person's career before the opportunity has appeared to reap the benefits.

Additionally, the 'marginal utility' of a creative product may decline for those individuals who have already made many contributions. One published poem means more to a young poet with no previous publications than to an established poet who has already put out several volumes of poetry. The net result of these economic decisions is a decline in creative output toward the closing years of the career. The age decrement is thus a natural repercussion of a gradual shift in the incentives and disincentives faced by creative individuals as they get older.

This economic model can explicate many other aspects of the relationship between creativity and age. Nonetheless, this model is not capable of explaining all the details. For example, it is not clear how it would account for the upturn in creativity that is often observed in the final years. What material incentives could possibly induce a dying creator to produce a swan song or final artistic testament? It would seem that the short-term costs of such projects would immensely overwhelm any anticipated long-term benefits. As in the case of the sociologists, economic models can probably account for only a portion of the phenomenon.

Psychological Theories

Psychologists, naturally, place even more emphasis on what is going on in the individual. Presumably the age changes in creativity are some function of cognitive, motivational, or dispositional variables that undergo transformations over the lifetime. For instance, the results of the psychometric studies may be used to explain the findings of the productivity studies. If divergent thinking represents a process fundamental to creative thought, and if scores on tests of divergent cognition decline in the latter part of life, then this trend may underlie the parallel drop in creative productivity. Furthermore, since different forms of these cognitive measures often exhibit distinct longitudinal trends, it is also possible to use these findings to explain the interdisciplinary contrasts in the age curves for creative output. Perhaps creativity in different disciplines requires a distinct mix of cognitive styles, in which each mixture will show an agewise trend that is a weighted average of the separate trends for each mental process entering the mix.

There are three main problems with this particular interpretation, however. First, and as pointed out earlier, the correlation between performance on creativity tests and the demonstration of creative behavior is by no means strong. Second, longitudinal and cross-sectional studies of these psychometric measures have focused on chronological rather than career age. Third, this explanation somewhat begs the core question; if productivity changes reflect underlying changes in mental capacities, the latter changes remain to be explained.

Other psychological interpretations do not suffer from these drawbacks. For example, according to one information-processing theory of creative productivity, the longitudinal trends in output emerge from the very process by which creative potential is converted into actual creative products. This theory predicts that the age curves will vary across disciplines in a manner that corresponds to the complexity and richness of the concepts and skills needed to generate and develop creative ideas. This theory also holds that the age curves depend on career age rather than chronological age. One distinctive asset of this theoretical account is that it makes very precise predictions about longitudinal changes in output across individuals and disciplines. Even so, this theory cannot explain certain details, such as the occurrence of the swan song phenomenon.

In fact, at present there is no theory of creativity that can deal successfully with all of the empirical findings reviewed earlier in this article. The relation between creativity and aging is perhaps far too complicated to permit simple theoretical interpretations.

See also: Information Processing/Cognition; Productivity and Age.

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Crime and Age

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Glossary

Cohort – Group of individuals sharing a statistical factor, such as age, in a demographic study.

Crime Rates – The incidence of crime related to the population.

Criminal Careers – Concept describing the onset of criminal activity, the types and number of crimes committed, and the termination of law-violating behavior.

Cross-Sectional Research – Studies groups of people of different ages at particular points in time.

Incidence of Crime – Rate of offending by offenders.

Index Offenses – Also known as Part I crimes.

Longitutional Research – Studies a particular group of people over a period of time.

Prevalence of Crime – Proportion of persons in a population who are offenders.

Property Crimes – Include burglary, larceny theft, motor vehicle theft, and arson.

Recidivism – Relapse into criminal behavior.

Uniform Crime Reports (UCR) – Annual reports on criminal activity collected and published by the Federal Bureau of Investigation (FBI). The reports divide offenses into two major categories: Part I crimes consist of murder, non-negligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny, and auto theft. Part II offenses include less serious crimes such as forgery, fraud, embezzlement, sex offenses, and others not meeting the FBI's criteria of seriousness and frequency to qualify for Part I.

Violent Crimes – Include murder, forcible rape, robbery, and aggravated assault.

Introduction

Criminology is the scientific study of crime and delinquency as social phenomena. This relatively young field of study has three principal divisions: (1) the sociology of law, which examines how laws are made and enforced; (2) criminal etiology, which studies the causes of crime; and (3) penology, which addresses society's response to crime and includes the study of the criminal justice system. Criminologists are social scientists who utilize the research methods of modern science to develop a body of general, verifiable principles regarding law, deviance, and crime. Criminological analysis looks upon crime and deviance not as isolated events but as highly complex forms of social behavior. To fully understand the meaning of deviance and crime, the discipline goes beyond the legal definitions of crime and examines the total social context within which deviance and lawlessness arise. In the process of studying the causes of crime, a vast body of research has identified age, gender, ethnicity, social class, family status, and community environments as major social correlates of crime.

This article explores in depth the relationship between age and crime and summarizes current information on this subject. The second section examines in some detail the age–crime curve as it emerges from national crime statistics collected by the Federal Bureau of Investigation (FBI). The third section discusses key statistical properties of the age–crime curve. The fourth section probes the significance of the age–crime curve and reviews the ongoing debate in criminology on the true relation between age and crime. The fifth section explores age as a critical social correlate of crime, along with other key variables. The sixth section considers age as a critical variable in the formation and termination of criminal careers. It also explores current criminal justice system responses to chronic offenders and questions the efficacy of these responses in terms of their potential for crime control and crime reduction. The seventh section investigates the effects of society's age structure on America's crime rate and tracks the expansion of the nation's juvenile population into the twenty-first century. The article concludes by assessing the implications of demographic changes on crime control and criminal justice policies.

The Relationship between Age and Crime

One of the few undisputed facts in criminology is the age distribution of crime. Official crime statistics, supported by victim survey research, show clearly that crime is a young man's game, with most serious crimes being committed by young males between the ages of 14 and 24. Beyond this brief vignette, age–crime curves show reliably that age is inversely related to criminal activity, with crime rates rising

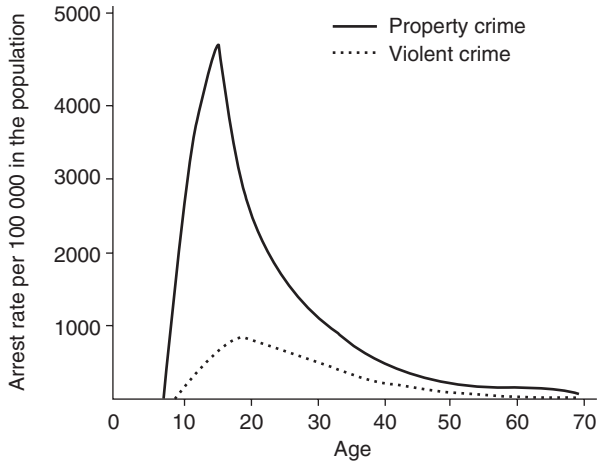

Figure 1 The relationship between age and crime. Property crime arrests peak at age 16 and at 18 for violent crime. There were 746.1 violent crimes and 4736.9 property crimes per 100 000 inhabitants in 1993. (From FBI, 1994. *Crime in the United States, 1993*. Washington, DC: Government Printing Office, pp. 10, 35, 227–228.)

rapidly from the minimum age of responsibility, peaking during adolescence, and then decreasing quickly. The decline is rapid at first, followed by a more gradual downward curve throughout a person's life cycle. **Figure 1** shows the property and violent crime rates for Americans per 100 000 in the population in 1993, as reported by the FBI. Property crime rate peaks at age 16, and the violent crime rate peaks at age 18. The relationship between age and crime is of great interest to criminology and vital to theoretical development in the discipline. Criminologists consider age to be a major correlate of crime, along with gender, ethnicity, social class, family status, and community environments.

Statistical Evidence of the Age–Crime Curve

Juveniles and young adults are arrested at disproportionate rates to their numbers in the general population. According to the FBI's Uniform Crime Reporting Index, youngsters between the ages of 10 and 17 represented 11.3% of the total US population in 1993. But they accounted for 18.4% of all violent crime arrests and for over one-third (33.2%) of all property crime arrests for that year. The disproportionate contribution of the young to the nation's crime problem jumps graphically to the fore when looking at the arrest statistics for all persons under the age of 25. That group makes up only 21.2% of the US population but accounts for more than half (58.3%) of all arrests for index property offenses and almost half (47.4%) of violent crime. The peak arrest age for most offenses is between 16 and 19, with property crime peaking at 16 and violent crime cresting at 18. After age 30, arrest rates decline. From age 50 on, arrest rates become marginal (1.3% and below). The decrease in criminal activity with increasing age is known as maturational reform or the 'aging-out effect'.

Significance of the Age–Crime Relationship: The Age Debate

The persistence of a distinct age–crime relationship has been documented by many studies across time, gender, ethnicity, types of offenses, and different cultures. This phenomenon and the consistency of the data have led some criminologists to suggest that the age–crime curve is invariant. They further believe that this distinct relationship between crime and age cannot be accounted for by changes in other factors with age. As a result, they maintain that age exerts a direct causal effect on crime. Given this causal effect, proponents of this school of thought suggest that the study of the age–crime relationship has little relevance for the study of crime, because all persons commit less crime as they age regardless of ethnicity, gender, social class, family, or any other variable.

On the opposite side of this age–crime debate is another school of thought, pointing to inherent weaknesses in aggregate, cross-sectional statistics, such as those featured in the nation's Uniform Crime Reports. It notes that although these data depict variations in the prevalence of crime, they offer little information on the incidence of crime. In fact, aggregate age–crime curves are singularly unyielding about age–crime curves for individual cases. This is because crime incidence varies considerably between the beginning and end of individual criminal careers. It also varies by the types of crimes that are committed. For example, vandalism or motor vehicle theft are clearly crimes of adolescence. They peak early, when youngsters are between the ages of 15 and 16. By contrast, white-collar crimes such as fraud or embezzlement peak relatively late, when perpetrators are in their late twenties and early thirties. Furthermore, just because the aggregate age–crime curve declines precipitously after adolescence, it does not necessarily signify that the number of crimes committed by every offender declines in a similar fashion. In fact, many cross-cultural, longitudinal research studies have demonstrated that although the frequency of criminal offending does follow the dictates of the age–crime curve for a majority of offenders, some very active individuals continue to violate the law unabated.

Age as an Important Determinant in the Etiology of Crime

Questions of why some individuals turn to crime while others do not and why most youthful offenders 'age out' of criminal activities while others persist in offending, have prompted a good deal of prospective and retrospective longitudinal research on the causes of crime. The results of these efforts indicate that onset, frequency, and cessation of criminal offending varies, depending on a number of biological, individual, and social factors.

Biological and individual factors help account for the shape of the age–crime curve because many criminal activities are contingent upon certain levels of physical and mental development. For example, rising testosterone levels in young males are consistently linked to aggression and violent behavior during adolescence, when immaturity, the pursuit of immediate gratification, and risk-taking behavior are also highly prevalent. As adolescents become adults, physical and mental maturation begin to play key roles in their desistance from crime. In a similar vein, the commission of some types of crimes, such as robbery or rape, is contingent upon certain degrees of strength, force, and agility. With increasing age, these offenders lose their physical power to assault, rob, escape, and avoid apprehension.

Although biology and individual factors do set some of the parameters of the age–crime curve, they fall short of explaining it. Adequate explanations depend on linking the curve to changes in a person's social environment. To that end, criminological research has identified a number of social factors that are of greater importance in explaining the age–crime curve than those focusing exclusively on changes in a person's biological or personal characteristics. The following behavioral factors are consistently associated with very serious, violent, and chronic juvenile crime: (1) dysfunctional families; (2) physical or sexual abuse; (3) delinquent peer groups; (4) poor school performance; and (5) high-crime neighborhoods. As the United States enters the twenty-first century, there is nothing on the horizon in terms of legislation or policy development that effectively responds to any of these factors, which does not bode well for the nation's crime rate or crime control.

Dysfunctional Families

Historically, the family has carried the primary responsibility for the socialization of children. Basic personality traits, perceptions of right and wrong, and personal values are formed within this primary social setting at an early age, long before the other socializing institutions, such as religion, education, or the workplace begin to exert their influence. Socialization is an integrative process of moral internalization and informal and formal education. Successful socialization implies civilization and, by definition, law-abiding behavior.

Most criminologists agree that a stable, secure, and mutually supportive family is exceedingly important in delinquency prevention. Conversely, children growing up in a family filled with violence, abuse, and neglect are most likely to embark on a life of delinquency and crime. The simple truth is that children raised in dysfunctional families have difficulty developing the prosocial identities and values needed to become productive, law-abiding citizens. The following are major indicators of the breakdown of the American family.

The number of children raised in homes broken by divorce, separation, desertion, or death is escalating. The nation's divorce rate is among the highest recorded in the world. The birth rate for unmarried women is fast approaching 50 births per 1000. Teenage pregnancy rates are among the highest in developed nations. The number of households headed by women has more than doubled in less than one generation. More than half of all mothers with school-aged children work outside the home, most out of economic necessity. The result is a steadily rising number of children who find themselves under the care of a single parent, a working mother, a day nursery, and too often, a television set. The percentage of children who do not have full-time parental supervision at home is close to 60% and rising.

Research on the effects of rapid social change and family disruption on crime is extensive and discouraging. Strong ties have been established between parental criminality and delinquency in children. Although the precise causes of intergenerational deviance are not yet known, there is some evidence of a genetic, psychological, and social factor linkage. Much family dysfunction is also related to a growing problem with parental alcohol and substance abuse. For example, there is a strong association between substance abuse, child maltreatment, and infants born with fetal alcohol syndrome or congenital drug addiction. Children raised by substance-abusing adults also have a much greater propensity to develop substance-abuse problems themselves, when compared to youths raised in drug-free home environments. Finally, certain child-rearing practices have emerged as primary factors leading to delinquent offspring. They include inadequate or inconsistent parenting, such as disciplinary practices that alternate between harshness and overindulgence; the use of severe corporal punishment; treating children with coldness and distance; and

exposing children to an incessant barrage of parental conflict.

Physical and Sexual Abuse

The correlation between violent physical or sexual child abuse and delinquency is positive and strong. Although estimates vary, more than 1 million children are abused and tortured in any given year by their parents or caregivers seriously enough to require hospital treatment. Unreported child abuse may be four to six times higher. The number of children who die as a result of parental maltreatment is estimated at between 2000 and 5000 in any given year. Research evidence has consistently linked physical or sexual abuse to risky sexual behaviors, particularly among girls, and to substance abuse, illegitimacy, and suicide. Furthermore, children already vulnerable with neurological and psychological problems seem to become prime candidates for delinquency not only if they are physically abused, but also if they merely witness habitual violence and brutality in their homes. Serious physical abuse can cause neurological or psychomotor disturbances, and children with such impairments have been found to disproportionately exhibit a tendency toward very serious and sometimes brutal violence.

Delinquent Peer Groups

As children mature, the influence and control of parents wanes and peer influence heightens. Crime statistics show that delinquent acts tend to be committed in small groups, rather than by youths acting alone. These statistics coupled with the fact that most children gravitate to forming close-knit peer groups during their early teenage years provide the single best explanation for the rapid escalation of delinquency and crime depicted by the age–crime curve. Although many desist offending, there is ample empirical evidence that youngsters who are involved with delinquent friends, belong to gangs, and otherwise associate with deviant persons are most likely to become involved in delinquency and crime.

Poor School Performance

The failure of schools as an agent of socialization is well documented, especially in socioeconomically deprived urban environments. Even though no clear causal relationship has been established between school failure and crime, there is agreement among criminologists that educational institutions lag in fulfilling their primary socialization function in modern society. The rising level of student violence and vandalism during the past two decades is well documented. When considering the amount of time children spend at school, it comes as no surprise that youngsters are at greater risk of violence in and around schools than anywhere else. Pilfering, assaults, robberies, fights, and racial antagonisms are a major part of school life and especially pronounced in urban schools. With the exception of trespassing and breaking and entering, most crimes committed in schools are perpetrated by the students in attendance. Teacher victimization through property crime and assault is frequent. Poor schooling and negative attitudes toward school are strongly related to delinquency and crime, substance abuse, disdain for authority, increased social fears, racism, and reduced productivity. Absenteeism and lack of discipline are major problems. Too many schools have watered-down curricula and reflect an alienated, prisonlike atmosphere. Many teachers, unappreciated by the public and their charges, are also alienated, demoralized, and prone to burnout. The disruptions, crime, and vandalism have taken their toll. Achievement scores are low, with many schools graduating technological illiterates, and more disturbingly, too many functional illiterates, ill equipped to face a job market requiring ever more knowledge and skills.

High-Crime Neighborhoods

Many of America's inner-city neighborhoods are characterized by poverty, transience, high population density, neglect, and physical deterioration. They are also marked by exceedingly high crime rates when compared to more affluent residential areas. Inner cities have high levels of unemployment, especially for members of minority groups. Even though there is no direct cause-and-effect relationship between poverty and crime (many single parents living in high-risk areas do not produce delinquent children), there is very strong evidence of structural linkages between family disruption, failing public school systems, economic marginality, declining low-skilled, blue-collar employment opportunities, and crime in high-risk, inner-city neighborhoods. Life in such neighborhoods breeds cynicism and alienation. Devoid of positive social control, such areas amplify criminogenic forces and further destabilize these areas. In that light, social, physical, and material conditions of neighborhoods exert an independent effect on delinquency and crime over which individual residents have little, if any, control.

Age and Career Offenders

Many studies analyzing delinquency and crime patterns in cohorts show that any given group contains a relatively small number of repeat offenders who

commit a disproportionately large number of crimes. This 'chronic offender group' (approximately 8%) is responsible for more than half of all the offenses committed, including a large portion of homicides, rapes, robberies, and aggravated assaults. Although the road to a chronic criminal career is highly complex and defies simple explanations, the studies agree on the following points. Most delinquents do not become chronic offenders. A few mischievous and petty delinquencies do not usually lead to an acceleration of serious criminal offending. Compared with conventional delinquent youths, chronic offenders begin their criminal careers at very young ages, often before reaching the age of 10. In fact, age at the onset of offending is the single best predictor of becoming chronic offenders and embarking on adult criminal careers. According to these studies, the younger a person is when first arrested, convicted, or confined for any criminal behavior, the more likely it is for that individual to continue offending. Offense patterns of chronic delinquents are often characterized by excessive violence, destruction, and lack of remorse. Calculations of the average lengths of criminal careers show them to be about 6 years, with career lengths peaking between the ages of 30 and 40. These findings have great potential for crime control and penal policy development. This is because if chronic offenders could be correctly identified and incarcerated for long periods of time, the crime rate should decline considerably.

Responding to these findings, Congress and state governments have passed a wide range of legislative initiatives during the past few years. Rooted in chronic offender research, these efforts are designed to deal more effectively with the nation's mounting crime problem. They do so by targeting high-risk, violent, and persistent offenders for rigorous prosecution. If found guilty in a court of law, such offenders are sentenced to long periods of incarceration, including life without parole. Advocates of longer sentences assume that they will both reduce crime and, ultimately, save taxpayer money. This is because they believe that such sentences will not only decrease the cost of victimization through incapacitation, but will also reduce the substantial costs of rearrest and reprocessing of repeat offenders by the criminal justice system.

Yet in spite of these dramatic legislative changes in sentencing, it is not known whether they will ultimately achieve the desired effect of crime reduction. This is because the research evidence on selective incapacitation is still incomplete. At present, criminologists do not yet have the ability to predict precisely which offenders present unusually high risks for recidivism and violence. Obversely, there is a similar lack of knowledge to correctly predict which offenders represent unusually low risks to society. The result has been legislative overkill. Present sentencing schemes cast too wide a net in their efforts to incapacitate and punish the serious, repeat offender. In the process, too many criminals are incarcerated whose crimes are minor and who do not pose a threat to the community.

The cumulative impact of career offender laws and related harsh sentences for repeat offenders has led this nation to the highest incarceration rate in the world, with over 350 prisoners per 100 000 US residents! To date, prison populations have increased close to a million persons in state and federal prisons. The cost of maintaining these prisoners has risen concomitantly, and will reach $19 billion in 1995, excluding the costs of holding prisoners in the nation's city and county jails. If current trends continue unabated, the costs of incarceration are destined to rise further. This is because of the unprecedented growth of lifers and elderly in prisons, whose healthcare needs double and triple the cost of caring for younger inmates in the general prison population.

Considering what is known about the relationship between age and crime, current developments in criminal justice countervail existing knowledge: statistically speaking, recidivism is known to decline with increases in age. Because offending at an early age is highly predictive of long criminal careers, scarce public resources would be better focused on crime prevention rather than on aging and geriatric inmates, whose criminal careers have peaked and decelerated long ago.

Age Structure and Crime

Because crime varies with age, changes in the age structure of society exert an important impact on the crime rate independent of the other known factors, such as dysfunctional families, schools, peers, and neighborhoods. The Baby Boom after World War II is well known and documented. The twin promises of peace and prosperity accelerated the nation's marriage and birth rates with highly predictable consequences. When the Baby Boom generation reached its most crime-prone years during the 1960s, the country's crime rate rose precipitously. By 1980, the crime rate peaked at 5950 per 100 000 in the population and declined. A decade later, index crimes were down, along with the proportion of juveniles in the total population. Since then, index crimes have been falling, with minor fluctuations. There have been further small decreases in the national crime rate since 1990. However, recent crime rates conceal two highly divergent and troubling trends: although

adult crime rates are declining as the Baby Boom generation ages, juvenile violent crime has increased rapidly. An examination of the nation's homicide rate, calculated per 100 000 inhabitants, illuminates the problem. Since 1985, the homicide rate for adults aged 25 and over has steadily declined from 8 to 5.2% in 1993. During the same time, the homicide rate for young adults aged 18 to 24 has increased from 16 to 26%. Worst of all, for juveniles aged 14 to 17, the homicide rate has more than doubled from 7 to almost 19%. Considering the fact that the nation's adolescent population will expand to 23% by 2005, the problem of rapidly rising serious, violent juvenile crime will only be compounded.

Summary

In summary, the state of criminological knowledge about the relationship between age and crime indicates that current criminal justice policies are misdirected. If today's unacceptably high crime rates are to be reversed, and more importantly, if a new crime wave is to be averted, the focus should be on primary prevention. This is best accomplished by assisting dysfunctional families, juveniles, and school systems outside the criminal justice system and by early intervention programs for youths within the system.

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Critical Gerontology

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Glossary

Aging Enterprise – Term to describe how the aged are treated as a commodity in society and how age-segregated policies fuel this further by singling out, stigmatizing, and isolating the aged from the rest of society.

Humanistic Gerontology (also called Cultural Gerontology) – the study of the interplay and recursive relationships of culture, structure, and agency.

Introduction

Critical gerontology is indebted to a range of theoretical and philosophical traditions, notably those of Antonio Gramsci and the Frankfurt School; conflict theorists including neo-Marxist and neo-Weberian state theorists such as Claus Offe and James O'Connor; feminist theorists, particularly of patriarchy and the state; and theorists of institutional racism and inequality such as Michael Omi and Henry Winant. Other theoretical influences include cultural studies, social constructionism, psychoanalytic perspectives, the sociology of knowledge, and work on globalization and risk.

Each of these theoretical strands has been incorporated into different aspects of critical gerontology. This work has evolved under a number of rubrics, including radical gerontology, political gerontology, the political economy of aging, the moral economy of aging, and cultural gerontology. This article first explores the intellectual origins of critical gerontology; second, identifies its main theoretical strands; and third, considers possible future developments within this perspective.

Origins of Critical Gerontology

The overall project of a critical gerontology has been to provide alternative theoretical frameworks and emancipatory knowledge, addressed toward

concerns of social inequalities and social justice. The initial and most developed area of critical gerontology is the political economy of aging, now considered part of mainstream theory within the field of aging. This approach, which emerged in the late 1970s through the work of scholars such as Carroll Estes in the United States, Peter Townsend and Alan Walker in the United Kingdom, John Myles in Canada, and Anne Marie Guillemard in France, examines the aging process and its social construction as problematic, to be understood only in the context of the larger social forces of politics, class, and social status such as race, ethnicity, gender, and able-bodiedness. From the beginning, the study of ideas and ideology has been central to understanding the social construction of old age and societal aging, the problems defined therein, and the perceived appropriate and feasible lines of public and private action. Power struggles over ideology are understood to reflect and reproduce the dominant social relations that vitally frame the issues of old age and aging, determining how state policy addresses these phenomena in society. As a major vehicle for promoting powerful interests, ideologies reflect a particular world view of later life. Goran Therborn observes, in support of this point, that ideologies delimit public understanding of what is, what is good, and what is possible. In the case of age, they denote first the importance of recognizing and valuing differences between groups of people who are growing old; second, the possibilities for solidarity based on age, across generations, and between social groups with shared interests; and third, the likelihood of developing alternatives to established expectations about the nature of social aging and aging societies.

Critical gerontology uses a conflict perspective to demonstrate how power struggles within society result in various divisions and inequalities, these having significant consequences for the trajectory of the life course and the life chances of individuals in old age. Political economists have criticized the dearth of theoretical and empirical attention to social and structural factors that influence and shape individual aging and the preoccupation of gerontology with features such as life cycle development, individual adjustment to old age, and so-called successful aging.

The critical perspectives in this approach have been twofold. First, they have investigated the institutional roles and powerful structural interests both within and between the state and different corporate sectors as well as the larger economic system of capitalism and other social institutions. This work has examined the impact of the resulting social relations on the family and sex and gender system as institutions, especially with regard to society's least powerful, most disadvantaged individuals. Second, critical perspectives have provided a commitment to social justice and to praxis by linking social analysis to action and political change. Robert Butler's influential book *Why Survive? Being Old in America* anticipated critical gerontology with its attack on ageism and its call for political and social change in defense of older people and a better society. More concretely, the goal of praxis is to understand and change those structures of dominance that produce and reproduce social inequality and injustice.

In Europe and the United States, old age and aging have been constructed and regarded as a problem of the welfare state. With globalization and the increasing strength of financial transnational capitalism, the focus on the state in developed and developing nations is increasingly centered on conflicts over the role of the welfare state in the financing of care and support for groups such as older people. Much of critical gerontology has taken as a central problem the divisions of income, wealth, education, and other resources, with particular interest in their distribution by race, ethnicity, class, gender, and age. A major concern is how the institutions of the family, the market, and the state are organized and function to produce social policy and their related outcomes at the individual, community, and societal levels. Conflicts over the allocation and control of symbolic and material resources are central processes for investigation in order to understand policy formation and the distributional consequences for different segments of the older population.

Carroll Estes has refined the political economy of aging approach, identifying multiple analytic levels, including (1) financial and postindustrial capital and its globalization, (2) the state, (3) the sex/gender system including the family, (4) race, ethnicity, and racism (institutional racism), and (5) the broader public and the individual citizen. Applied to social policy and aging, this perspective seeks to understand and analyze the human and social outcomes of power struggles, especially those occurring on the meso (organizational and institutional) and macro (national and global) levels as they affect the micro level of the everyday lives of people.

Critical Gerontology and the Role of the State

The role of capital and the capitalist system is a key element in the political economy of aging. Major concerns are the relationship between old age policy and the economics and politics of markets.

The power of corporate capital to influence programs and policies for the benefit of business at home, nationally, and around the globe is a key topic of study. An additional area for research is the exercise of ideological, political, and financial might in the service of the privatization of state programs (e.g., Social Security and Medicare in the United States). Of considerable interest are strategies utilized by different financial and industrial sectors to pursue contracting out and other low-wage strategies that weaken the power and economic resources of labor, women, and minority populations. From a political economy perspective, a central issue concerns the effect (real or perceived) that public spending has on the functions of the private economy in terms of ensuring capital flows for profits and investments.

Political economy perspectives view the state as central to the understanding of old age and the life chances of older men and women because of its power to (1) allocate and distribute scarce resources to ensure the survival and growth of the economy, (2) mediate the different needs and demands across different social groups (gender, race, ethnicity, class, and generation), and (3) ameliorate social conditions that could threaten the existing order and/or disturb the power of entrenched vested interests. Within critical political economy, state theory assumes the conflict paradigm, which conceives of the social order as being held together by the dominance of certain groups over others. The outcomes of power struggles are examined in terms of how society is organized and functions. The social order (the status quo) is seen as being held together by constraint (in the sense that some are able to impose their ideas, material interests, and actions over others) rather than by popular consensus. Societal institutions such as work organizations and medicine are examined in terms of how they are organized and operate. The state, in its multiple institutional forms (e.g., legislative, executive, judicial, military, educational) actively participates in these struggles, but also reflects various forms of the interests of the most powerful. Multiple variants of state theory compete and co-exist as explanations in the work of critical gerontologists: elite, managerial, class, feminist, and race theories of the state. At the same time, gerontological work on the state remains limited and has increasingly become the purview of scholars working on the study of globalization (*see* Globalization and Aging).

Critical Gerontology and the Aging Enterprise

An important link between the analytic levels identified previously is found in the different ways that old age and the aged are defined and treated and their relationship both to personal interactions and self-concept, and to the structural arrangements and resource disparities in society. The social constructions of old age and aging are seen as a product of the attributions of others that are differentially influenced by those with the power to impose their particular views of reality, including ideologies and frames about what old age and aging represent. These social constructions produce positive and negative associations with, and connotations of, growing old as well as notions of what it is possible and appropriate to alter or remedy at all societal levels: individual, institutional, and systemic. It is relevant to point out, however, that, in the sense that the experience of old age is socially produced, it is neither immutable nor given entirely by the prevailing distribution of power and constructions of reality. Those who shape and determine the definition of the situation wield disproportionate control over the societal provision of old age benefits, the personal and public costs of care, and the structure of care provision. Nevertheless, individuals retain a strong sense of needing to control their lives and the potential to resist, individually and collectively. This is the human agency that is the driving force behind the development of critical knowledge in the pursuit of social change toward a more just society.

One major product of the relations between capital, the state, and the public that is of major consequence for older people is the development of the aging enterprise, first analyzed in the United States by Carroll Estes (1979) in the late 1970s. This term was introduced to call attention to "…how the aged are often processed and treated as a commodity in our society and to the fact that the age-segregated policies that fuel the aging enterprise are socially divisive 'solutions' that single-out, stigmatize, and isolate the aged from the rest of society." The aging enterprise is constructed through the various agencies comprising the medical industrial complex. This manages problems of aging through (in the United States) the provision of privately rendered medical and high-tech services (usually proprietary) at the individual level and through for-profit nursing homes. The framing (definition) and policy treatment of the needs of the old for health and social support promote the construction of the problem of aging as the need for market goods rather than for a social good such as universal entitlement to the continuity of benefits and a caring community without fear of famine. This framing underscores the key trends in market-driven reform and restructuring, the explosive growth of proprietary care, corporate mergers, for-profit managed care, and pharmaceuticals with increasing

consolidation and concentration of private medical, technological, insurance, and finance capital, not only on the national but also on the global scale.

In both medical and long-term care, major social processes of critical gerontological study include the successful commodification of aging through the biomedicalization of old age and the processes of privatization, competition, rationalization through care (cost) management, and the devolution of federal responsibility to ever lower levels of government and to the individual and family as well as the increasing informalization of care, with the bulk of long-term care provided free by women caregivers, often with the negative consequences of increased stress, morbidity, mortality, and poverty.

Race and Feminist Perspectives in Critical Gerontology

The examination of race and institutional racism is central to understanding both the origins and consequences of old age policy and the effects on diverse racial and ethnic groups, both individually and in the aggregate. State policy is examined in terms of how it is linked with race and ethnicity through both local and global processes of imperialism and immigration policies that facilitate the exploitation and oppression of Blacks and other minorities. Race and institutional racism within social structures and unequal power relations affect the political processing and treatment of different subpopulations, in large part depending upon the relationship to and experience with the dominant cultural, political, and economic systems. Income and wealth inequalities as well as those in health and health-care access are crucial in determining the (multiple) jeopardies and outcomes that may be experienced or endured in old age. Regrettably, analyses of the dimensions of race, ethnicity, and institutional racism in old age and aging societies represent one of the most underdeveloped areas within critical gerontology.

Feminist theory is an essential part of critical gerontology. Gender is a central organizing principle in the economic and power relations of societal institutions as well as social life throughout the life course, shaping the individual experience of old age and aging and the distribution of resources in old age to men and women. The state, the medical industrial complex, women's devalued role in social reproduction and family caregiving, and globalization are each examined as vehicles generating socioeconomic and other inequalities confronting women (and variously so) across the life course. In feminist political economy, attention is given not only to gender relations and sex, but also to social class, race and ethnicity, nation, and age. New principles of feminist economics incorporate non-market activities and the household as loci of economic activity and the concepts of cooperation and caring (not just competition) as appropriate areas for economic analysis.

A number of critical feminist scholars have contended that the state is a major vehicle for the subjugation of women and that the state is in itself a patriarchal institution. Feminist critical gerontologists have demonstrated that older women are more dependent upon the state than older men. A major goal of feminist political economy of aging is understanding how the state, multinational corporations, and capitalism, the sex and gender system, and institutional racism conjointly produce and reproduce the dominant institutions that render a large proportion of older women (particularly minority and non-married women) vulnerable and dependent throughout their life course. Important considerations are how gendered state policies define the problems of aging as individual problems of self-care and private family responsibility predicated on women's unpaid long-term care labor and, when formal care is required and this free care-work cannot be extracted from women, the purchase of care services sold for profit and usually provided by underpaid women. Research examines the relationships between the situation of older women and state roles that advance the interests of capital accumulation, a gender ideology, and the legitimation of capitalist and patriarchal social relations. Work from a critical feminist perspective on old age seeks to advance reflexivity and a feminist epistemology, explicitly working outside the frame of patriarchal thought. Following Dorothy Smith (women's standpoint, ruling relations, and institutional ethnography), Nancy Hartsock (feminist standpoint), and Sandra Harding (the science question in feminism), these approaches extol the value and validity of women's knowledge of everyday life while also challenging mainstream masculinist social science frameworks and methods.

Critical Gerontology and Social Inequality

Reflecting the influence of race and feminist perspectives, a central aim of critical gerontology has been to explore the characteristics of inequality as experienced by older people living within advanced capitalist societies. Patricia Hill Collins' concept of interlocking systems of oppression is part of a broader critical work on social inequality, as it points to the multiplier and layering effects of race/ethnicity, gender, class, age, and disability that reflect

and illuminate social structure and individual experience. Macro-level connections link systems of oppression such as race and gender with the state and other social institutions. At the micro level, intersectionality denotes the processes by which each individual and group occupies a social position with interlocking structures of oppression. Attention to social class has been a major issue for those taking a political economy approach within gerontology, with the view taken that older people are as deeply (or more) divided along class and other structural lines as younger and middle-aged adults. Critical perspectives have begun to clarify the range of processes likely to maintain social divisions in later life. The role of education appears highly influential and may play a crucial role in improving access to stocks of social and cultural capital, thus increasing psychological resources, healthy lifestyles, and general well-being.

An additional approach to understanding social divisions concerns the multidimensional way in which inequality and deprivation might be experienced in old age. In this context, the concept of social exclusion has been helpful in pointing to the range of factors that might limit involvement in mainstream social institutions. The idea of social exclusion is intended to recognize the range of problems experienced by older people living in poverty – material difficulties, certainly, but also social isolation, detachment, and low participation in mainstream institutions. Research in Britain by Scharf et al. demonstrates the extent to which older people living in areas of acute social deprivation (typically inner city metropolitan areas) may face multiple forms of exclusion with clear links operating between different domains of exclusion. In particular, there appears to be a strong relationship between exclusion from social relations and exclusion from material resources, confirming the way in which poverty and deprivation can combine to restrict participation in a range of informal social relationships. Such research raises issues about the role of social institutions in supporting older people's participation in daily life and, conversely, their potential to contribute to disengagement when financial and social resources drop below certain levels.

A central issue concerns future trends in social inequality through the life course. The likelihood is for a continuation of patterns of cumulative advantage/disadvantage, with these patterns constructed around gender, cohort, class, and ethnic divides. Gender is likely to remain a crucial component of inequality, with women especially affected by changes to the organization of welfare and social security. Price and Ginn, analyzing British data, found that divorced and separated women are at a particularly high risk of poverty in later life and that for this group this matches the individual poverty and lack of independent pension building – a situation from which women may find it difficult to recover if they are caring for young children and are in the part-time labor force.

Recognition of growing diversity and inequality within cohorts is another major theme within critical gerontology. Studies of the Baby Boom generation are likely to show wide variations in future income and consumption prospects, reflecting educational, occupational, gender, class, and other social factors. As shown by Johnson and Crystal from their study using US longitudinal data, there is the prospect for high income inequalities among American Baby Boomers during their retirement years, a finding matched in comparable European studies. This may be compounded by changes in employment conditions across the class divide, with improvements in the remuneration of professional and white-collar workers on the one side but with reduced wages, benefits, and job security for blue-collar workers on the other. The driving factors here include the growth of flexible employment (associated with decline in company benefits), changes to pensions with the move from defined benefit to defined contribution schemes, and the further deterioration in manufacturing employment in developed economies. More generally, the inequalities associated with the rise of globalization is an issue for critical gerontologists to address, as foregrounded in work by Chris Phillipson, Carroll Estes, and John Vincent and others (*see* Globalization and Aging).

Humanistic Perspectives in Critical Gerontology

Another important element within critical gerontology is the development of cultural and humanistic gerontology, sometimes referred to as moral economy or more broadly as cultural gerontology. This approach has gained popularity, as the classical theoretical opposition of structure versus agency and culture versus structure has given way to an appreciation of the interplay and recursive relationships of culture, structure, and agency. Cultural gerontology is part of the trend toward theories that reject the sole determinacy of economics in explaining social institutions such as the state and old age policy. The approach reflects a reformulation of the unidirectional causality implied in the classical base superstructure model of Marxism. What has followed is an intensified focus on questions of meaning and experience as applied to later life.

In the United States, scholars such as Tom Cole, Meredith Minkler, Joe Hendricks, and Anne Robertson, working from a moral economy perspective in gerontology, have brought attention to social norms and reciprocal obligations and relations in society and their role in the social integration and social control of the elderly and the workforce. Moral economy scholars examine popular consensus concerning the legitimacy of certain practices based upon shared views of social norms and obligations such as reciprocity and generational equity in relation to distributive and economic justice.

Humanistic gerontology adds yet another dimension to critical approaches to aging by seeking both to critique existing theories and to construct new positive models of aging based on research by historians, ethicists, and other social scientists. Harry Moody has identified several goals for the critical humanistic perspective in gerontology: (1) development of theories that emphasize and reveal the subjective and interpretive dimensions of aging, (2) commitment to praxis and social change, and (3) the production of emancipatory knowledge. Consistent with and complementary to the political economy, feminist, and race theories, this approach centers on the concepts and relations of power, social action, and social meanings as they pertain to aging. At its core, this approach is concerned with the absence of meaning affecting older people and the sense of doubt and uncertainty that is thought to permeate and influence their day-to-day lives and social relations.

A related focus in critical gerontology concerns the relationship between identity and adult aging, including understanding identity as managed and negotiated and representing both a source of restriction and a grounding for social action. In this approach, the varied experiences and meanings associated with old age and aging are the subject of study. This work has emerged as important for understanding emerging forms of human and political agency – and the effects of these on social policy and old age as well as individual and societal aging. Simon Biggs suggests that aging identities have been faced by two forms of excess: an excess of structure that confines the possibilities of adult aging to age stages and stereotypes and an excess of fluidity that disconnects aging from the material bases of experience that can lead to insecurity and risk. Both have served to place restrictions on acceptable forms of contemporary aging.

Three streams of social gerontology – that dealing with the humanistic and experiential side of aging and those attending to the meso institutional and the macro structural movements and forces – are each essential if the goal of understanding differences and inequalities among and between older people and other groups is to be achieved. Critical gerontologists including Jan Baars, Simon Biggs, Dale Dannefer, Chris Phillipson, and Alan Walker variously point to the problematics of postmodern social theory for gerontology. With Baars' concept, reflexive modernization, critical gerontology attempts to rescue the basic modernist ideals of self-fulfillment, solidarity, and human dignity, challenging approaches that remove experiences from the social structural frames within which they are created. Critical gerontologists caution against approaches that (1) individualize social and economic inequalities that dominate everyday life in old age and deflect attention away from the social, economic, and political forces that produce them, and (2) reject universal meta-narratives and truth-telling in ways that ignore or obliterate political power, economics, and sociocultural forces in the structuring of age-related outcomes. The contents, meaning, ideology, and consequences of the postmodern turn and poststructuralism in intellectual circles have produced intense debate within critical gerontology far beyond the parameters of this article; nevertheless, they foreshadow future scholarship in critical gerontology.

Future Developments in Critical Gerontology

Future developments in critical gerontology will be shaped by a commitment of its scholars to the larger intellectual project of critical theory understood as the critique and subversion of all forms of domination. The challenge to social gerontology and critical work therein is found at every level of human existence and analysis: macro, meso, and micro. The forces of accelerating global change, the increasing power of financial capital, deepening social inequalities, and the changing and challenging economic relations between workers and employers and between the people and their nation states are joined by other profound upheavals, cultural and religious conflicts, and the demographics, economics, and politics of societal and global aging – all of which have the potential to unravel the everyday life of groups of older people.

As new, evolving, and ruptured social relations profoundly affect the individual and societal experience of old age and aging, the existing conceptual and methodological tools within gerontology will need to be reexamined. The influences now affecting older people raise profound issues for the quality of their future lives. Important issues for study include developing critical theory and the larger project linking the personal to the political and the economic and the

cultural; theorizing and analyzing old age and the aging society in a global universe with attention to the state, citizenship, and social rights; understanding new social divisions and inequalities; and the critical study of intergenerational relations. In each of these areas, a major task is to illuminate alternative understandings and visions of what is possible in later life. A focus on the ideological is intended to open a critique of all that obscures and mystifies inequality and social injustice, including theoretical, epistemological, methodological, and empirical works. The critical lens aims to open up a distance between what people are told are the choices available to them, and their own views and expressions of their personal and collective needs. The distance facilitates the ability to discriminate between what we are taught to believe and the opportunities to build alternative possibilities for us and for our aging society. The emancipatory project necessitates both critique and distance to encourage a perception of the aging self as a conscious agent in spite of the circumstances in which social actors find themselves. Only then is it possible to discover and build upon common causes rather than disempowering differences between social groups. In this, the issue of solidarity re-emerges as a challenge to the age segregation, ageism, and growing inequalities and divisions in Western societies and across the globe.

See also: Ethnicity and Minorities; Globalization and Aging; Life Course; Politics of Aging; Theories of Aging: Social.

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Cultural and Ethnic Influences on Aging

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Glossary

Culture – Shared beliefs, knowledge, feelings, and objects.

Introduction

Worldwide increases in life expectancy and declines in fertility, nearly universal in extent, make the question of cultural and ethnic variation in the aging experience more pertinent today than ever before. People born in more developed countries today can expect to live 40 years longer than they would have had they been born at the turn of the twentieth century; but even less impressive gains in life expectancy in the developing countries mean large increases in the absolute numbers of elderly. Additionally, declining fertility (which reduces the number of young people entering a population) and increasingly effective medical care (which reduces death rates at all ages) have led to an increase in the proportion of older people alive across the globe.

By 2030, the proportion of people aged 65 or greater will reach 20% in most European and North American countries, and the same trends will result in similar age distributions somewhat later in less developed countries. But the time it takes to reach such proportions of older people will be much shorter in the developing world. For example, in France and Sweden it took 82 years and 114 years, respectively, for the population aged 65 and over to double from 7 to 14%. This same transition took only 18 years for Singapore, 20 years for the Republic of Korea, and 25 years for Japan. A similar process is at work in developing countries; for example, Sri Lanka, Jamaica, and Tunisia will each achieve this doubling over the next 25 years. Unlike the developed countries, these societies are becoming old without the pension, social welfare, and health-care systems of the developed nations, making old age a more precarious experience than it is in the more developed nations.

Increasing immigration from developing to developed countries and the greater birthrates of many immigrant populations also suggest that recognition of cultural and ethnic variation in aging will become increasingly important. How will provision of health care and aging services have to be modified to reach these ethnic minorities? To what degree will clinicians have to alter assessment of elder health and well-being in the face of this increasingly multicultural elder population? What kinds of outreach or innovation in service delivery will be required to close the gap in outcomes between majority and ethnic minority populations?

Defining Culture and Ethnicity

While culture and ethnicity are often used interchangeably, in fact it is important to keep them distinct because they refer to different components of personal identity and social status. For example, in the United States it is possible to self-identify as Asian or Latino, drawing on one's ancestry, appearance, and national allegiance, and yet participate fully in American culture, not know how to speak the language of one's grandparents, and not even know anyone in the home country. Ethnicity as it is usually conceived (as in census records) masks a great deal of variation in acculturation, language, and culture relevant to health behaviors and outcomes in later life. The same is true of race, and indeed many researchers in gerontology and clinical research have given up trying to separate race, ethnicity, and culture and simply speak of ethnoracial, ethnic/racial, or sociocultural groups. But culture and ethnicity do not map together well. In the socially mobile, tolerant United States, it is likely that people self-identifying as an ethnic minority will vary in the extent to which daily life is governed by cultural conventions typically associated with this ethnicity. With assimilation and longer duration in the United States, cultural differences wane, and hence adult children may find themselves facing the severe challenges of cross-cultural communication even within their own families. This challenge may become most apparent when adult children serve as go-betweens between elders and home-care paraprofessionals and clinicians, or when their own expectations for old age clash with those of their parents or grandparents.

By culture, anthropologists refer to shared beliefs, knowledge, feelings, and objects. These kinds of shared experience may differ from those of the majority culture and the expectations of professionals who provide key services, such as health-care providers. For example, medical anthropologists have identified a variety of indigenous conceptions that do not square with modern medicine, such as misconceptions about hypertension or the strength of medications. To this, we might add more general expectations about aging. Are ethnic minorities more or less likely to consider pain, limitation in activity, or cognitive impairment normal in old age? Do they expect more or less from old age than non-minorities? These questions have only recently become topics for research, and the little research available suggests that expectations regarding aging and care in old age may differ across cultures. For example, in the United States, minorities are less likely to use skilled nursing facilities and perhaps are more likely to tolerate dementia and old age disability at home.

More generally, cultures are likely to differ in what they emphasize in the aging experience. We know from gerontological research that the senescence of biological systems typical of late age leads to both positive and negative changes. With each additional decade of life, adults will see declines in strength and walking speed and slowing in reaction time, for example, but they will also see declines in addictive behaviors and crime, reduction in severe psychiatric disorders, and increased contact with close family. American culture stresses the negative features of aging; aging is something to be fought or covered up. In other cultures, the stress may be placed on the more positive elements, as among the Samia of Kenya, who boast of aging as a time to sit by the fire and be fed. Americans, by contrast, consider dependence and need for help in old age worse than death.

One productive approach to cross-cultural variation in expectations about aging is to turn to differences in conceptualization of the life course.

Anthropologists and historians have documented variation in the periodization of developmental processes, that is, how human development over the life span is divided into phases or stages. American ideology stresses discrete stages of adulthood: education, employment, retirement. The transition to retirement may be punctuated by a major journey or long-awaited indulgence postponed during one's career. In Taiwan, by contrast, human lives are likened to the growth cycle of rice. Major stages of life are defined in terms of fertility, decay, and reintegration into the earth. Beyond old age and death is ancestorhood, an important and valued stage of life.

In some social groups age is the dominant principle of social classification. The age-set systems of east Africa, the mandatory age-based clubs of Japan, the junior–senior distinctions in ranking systems (such as the military), and even the freshman through senior designations of colleges and fraternities all use age, or peer groupings roughly based on age, to assign social duties and privileges and to enforce group-wise transitions in status. With age as the prominent element of rank, old age should have greater prestige in such societies or organizations, yet case studies suggest that the position of the elderly in these societies varies considerably.

Relevance of Culture and Ethnicity for the Experience of Aging

When people think of old age, they first think of years or some other indicator of the passage of time (for example, in societies in which people do not use year-based calendars, these indicators might include the number of harvests completed, number of ritual cycles conducted, or number of relocations of dwellings). But even in contemporary cosmopolitan cultures, old age is not simply a matter of chronologic age. Survey results show that the age at which people are considered old varies according to one's own age (the older one is, the later old age is said to begin), gender (women date the start of old age at later ages), and socioeconomic status (old age is said to begin at younger ages among minorities, perhaps out of recognition of shorter life expectancies).

Similarly, when people are asked to group social statuses, chronological age is only one factor affecting ratings. Such cultural dimensions as productivity, vulnerability, and reproductive potential also matter, so that respondents group old people and children together in some cases, distinguishing them from people of middle age. This finding is consistent with research on the infantilization of older people. Baby talk is often used with older people with cognitive impairment or other disabilities, and terms typically reserved for children (for example, diminutives and saccharine terms) are often applied to older people. The reverse is also true: younger adults who are not active, not interested in new experiences or travel, not willing to switch careers, or slow, deliberate, or narrow-minded are often called old. This use of language suggests the negative conception of aging typical of American society. People are old not just because of their age but also because of their behavior, their health, their attitudes, their choices, and even their politics. Thus, in American society, adults can refuse to grow up, and people can insist on not acting their age. Marriages that cross generational lines (so-called May–December weddings) are disparaged and considered nearly incestuous. In many Asian and African societies, by contrast, large gaps in the age of marriage partners (with men much older than women) are not exceptional.

Clearly, these overall evaluations of old age, some subtle, some not, are part and parcel of the status accorded to elders. In all societies and perhaps more so in developing countries, deference and respect for the elderly may be universal (reflected very well in antiquity in Homer's description of a chariot race, in which the trophy is given to the slower elderly warrior just because he is old; the poet remarks that it would be unseemly to give it to the younger, faster competitors). Yet even in societies with well-developed traditions of respect for the elderly, reports of neglect and the precarious status of the elderly are accumulating. In developing countries, migration of young people to cities (or to other countries for employment) reduces the availability of family caregivers and may further jeopardize elders.

Variation in Resources Available upon Entry to Late Age: Health Disparities

Ethnic and cultural minorities enter old age with cumulative disadvantages. They are more likely to report poor health, perform more poorly overall on tests of physical and cognitive function, report a greater number of medical conditions, and on the whole have less wealth and poorer health insurance coverage. Reasons for poorer physical and cognitive performance are not completely clear but likely reflect less or poorer-quality education, more physically demanding occupational exposures over the life span, less access to medical care in child- and adulthood, and many other risk factors associated with lower socioeconomic status. Cultural status may also have an independent effect. For example, Hispanics in the San Luis Valley study are more likely to report

poorer health than White elders, even in analyses that adjust for health conditions and physical performance. On the other hand, minorities may have some advantages upon entry into old age. The Health and Aging Body Composition study found that African American men and women had better bone health than Whites and were less prone to fractures. But the same study has also shown poorer cardiovascular health among African American elders.

In the case of medical conditions, differences between White elders and minorities in the United States are impressive. In the 1990s White and minority elders both saw declines in mortality from heart disease, stroke, lung cancer, and breast cancer (and also in motor vehicle crashes, suicide, and homicide). In some cases, minority elder mortality declined to a greater degree. For example, stroke mortality declined 11.1% among African Americans, 8.2% among Hispanics, and 8.1% among Asian and Pacific Islanders, compared to a decline of 7.2% among White elders. (An exception to this pattern of decline is evident in Native American populations, which saw an increase of 2.6% in stroke mortality over this period.) These trends are welcome in that they reflect progress in eliminating disparities in health service access and outcomes. Still, overall differences in stroke mortality remain impressive. For example, age-adjusted death rates (deaths per 100 000) from stroke at the end of the 1990s were 23.3 for Whites and 42.5 for African Americans. Hispanic mortality from stroke is more similar to rates seen for Whites.

The case of heart disease, the largest source of mortality in old age, shows that some ethnic and cultural groups may face lower risks than the majority group. At the end of the 1990s, risk of death from cardiovascular disease (again, age-adjusted deaths per 100 000) was 123.6 for Whites and 188.0 for African Americans, but 84.2 for Hispanics, 97.1 for Native Americans, and 67.4 for Asians and Pacific Islanders. These figures should be interpreted with some caution, however, since they represent only a single source of mortality, and ethnic and racial minorities also suffer health disparities that increase mortality risk at early ages.

Disparities in the risk of physical disability in old age are also narrowing. Disability has declined 1–2% per year among African American and other elders, at least in the case of highly demanding household tasks. However, ethnic and cultural minorities report greater prevalence of disabilities. In the Health and Retirement Survey, African American elders were more likely than non-Hispanic Whites to report difficulty or need for help bathing (6.7 vs. 2.4%), using the toilet (7.4 vs. 3.0%), transferring from bed or chair (11.1 vs. 4.5%), dressing (12.6 vs. 5.7%), and walking across a room (8.5 vs. 3.5%). Similar differences were found for indicators of upper and lower body strength and dexterity, such as difficulty lifting and carrying 10 lbs (27.8 vs. 14.4%) or using fingers to grasp and handle objects (7.0 vs. 3.9%). These differences were even more pronounced in comparisons of inner city and suburban African Americans.

Some of these differences in prevalence may be explained by lower recourse to use of skilled nursing facilities by ethnic and cultural minorities. The most frail and disabled elderly are likely to reside in nursing homes. If a minority cultural group does not make use of nursing facilities to the same degree as other groups, its community-dwelling elderly will be more likely to include greater numbers of the very disabled. A good illustration of this bias can be seen in the San Luis Valley study of Hispanic elderly, which also found a greater prevalence of disability compared to White elderly when the sample was limited to community-dwelling elderly. However, when nursing home elders from the same survey were included, Hispanic and non-Hispanic Whites did not differ in the prevalence of disability. However, this absence of differences raises an even more intriguing question. How is it that Hispanic elderly enter old age with less income and education, yet do not show a greater prevalence of disability when compared to non-Hispanic Whites in the same region?

The same issues in cumulative disadvantage are evident for cognitive test performance and risk of dementia. Early estimates of the prevalence of Alzheimer's disease among community-dwelling elders were surprisingly high (about 10% of people aged 65 and older), in part because they were based on surveillance in the Italian enclaves of south Boston, a group that also shuns use of skilled nursing facilities. In fact, current estimates suggest about 5% of people aged 65 and older meet criteria for Alzheimer's disease. But the incidence, or risk of Alzheimer's disease, does indeed differ by cultural group status. In one prospective analysis limited to people without APOE-ε4, a genetic risk factor for Alzheimer's disease, Hispanics and African Americans faced a significantly higher risk of disease. By age 75, 2% of Whites and 9% of minorities met criteria for the disease. By age 80, about 9% of Whites and 21% of minorities were affected. These large differences in incidence persisted even with statistical control for differences between the race–ethnicity groups in a great variety of risk factors for Alzheimer's, such as years of school, family history of the disease, number of comorbid chronic disease conditions, and behaviors such as smoking and head injury.

Recalculating incidence using a stricter definition of dementia to identify only clear and obvious cases of Alzheimer's disease (moderate or more severe dementia) also did not eliminate differences between the race–ethnicity groups.

These differences in the risk of Alzheimer's by cultural status raise important questions. Do we overdiagnose minorities (and if so, why?), or do we underdiagnose Whites (and again, if so, why?)? Why should minorities be at greater risk of developing Alzheimer's? Is it because they enter later life already with poorer abilities? Or do they enter later life with abilities similar to Whites, but decline at a faster rate in old age? The first factor suggests an effect in the first 50 years of life, the second an effect in the second half of life.

Evidence suggests the first explanation is more likely to be true. In a study of non-demented community-dwelling elderly, 16.3% of Whites scored in the lowest third of memory performance, but 32.4% of African Americans and 44.4% of Hispanics scored in this range. This difference strongly supports the claim of early life events as a predictor of a key late-life outcome. Minority elders enter later life with less cognitive reserve. By contrast, the slope of memory score change over serial assessments, that is, the mean rate of decline, was not significantly different across the three race–ethnicity groups. Thus, cognitive performance in minorities did not decline at a faster rate. Baseline differences, differences that predate old age, appear to be responsible for the higher risk of Alzheimer's disease among ethnic and cultural minorities.

Variation in Family Caregiving and Intergenerational Exchange

Ethnic and cultural groups differ in their commitment to family care. African Americans are more likely than Whites to endorse the primacy of family care, and accordingly are less likely to make use of formal long-term care, including respite, home care, adult day programs, skilled nursing facilities, and hospice. Similarly, Latinas delay institutionalization relative to Whites; a higher cultural value assigned to family care leads to more positive views of family caregiving, which in turn leads to a more negative evaluation of skilled nursing facilities as an option for dementia or end-of-life care. These differences, however, may be narrowing. With the rise of alternative living situations for the frailest elderly, such as assistive living and continuing care retirement communities, the proportion of White elders in skilled nursing facilities has declined and the proportion of minorities has increased.

Differences in commitment to family care are based on cultural norms of filial piety or obligation. The Chinese concept of *xiao*, or filial piety, is a well-developed element in Chinese culture, which, however, is strongly gendered, so that the burden of such care falls on adult daughters or daughters-in-law, not sons. Caregiving in American families shows a more variegated pattern, both in underlying concepts and in the division of labor (though caregiving to disabled elders remains mostly women's work). Ideas of filial obligation are linked to conceptions of parental dependency. Caregivers who view the obligation to provide care as a matter of reciprocity ("she was a good mother; now I need to take care of her") are likely to view the elders as simply sick, disabled, or in need. Caregivers who view the obligation as a matter of bodily connection ("she is my mother") are more likely to speak of caregiving as a reversal of roles, viewing the parent's decline as a return to childhood. Americans who view caregiving as a matter of reciprocity may be more likely to use the nursing home as a care option. This recourse usually occurs late in the caregiving career, when families perceive that the bounds of reasonable reciprocity (and family ability to meet elder needs) have been exceeded. In the United States, norms of filial obligation are heavily influenced by education, with greater acceptability and use of nursing homes evident among more highly educated people.

With norms of filial obligation and positive appraisals of caregiving demands, ethnic and cultural minorities are more likely to report satisfaction in caregiving. Latina caregivers report lower appraisals of stress and greater perceived benefits of caregiving; they also make greater use of religious coping than Caucasian caregivers. Similarly, African American caregivers report lower anxiety, greater well-being, and more perceived benefits of caregiving than Caucasian caregivers.

Is caregiving an extension of other intergenerational relationships, such as provision of financial and other kinds of instrumental support? A prospective study of relationships between adult child and parents, first when children were in their 20s and parents in their 40–50s (1970s) and again 25 years later (1990s), yields some insight. Parents who spent more time with their adult children and provided greater economic support were more likely to receive instrumental and caregiving support from adult children 25 years later.

Evidence from a number of different settings suggests that this investment or insurance mechanism for intergenerational relationships may hold across cultures. For example, in a Taiwanese sample, the odds of nursing home admission were lower for

elderly who provided instrumental assistance to their families before they were disabled. However, in other settings, where the norm of filial obligation is paramount, the correlation between help provided early in life and the provision of caregiving later in life may be less strong.

It is also worth noting that exchanges of goods, time, and care are also a vehicle for perpetuating continuity across the generations. When elders are no longer able to reciprocate in such exchanges, maintaining continuity of the family becomes more difficult, and this threat may be more or less well managed across cultures. Cross-cultural investigation of this area is relatively undeveloped.

Relevance of Culture and Ethnicity for Assessment of Elderly

Cognitive Status

Despite some thought that ethnic or cultural minorities may differ in the recognition of dementia in elders (for example, finding dementia behaviors more acceptable), in fact such differences appear to be an artifact of knowledge about dementia or access to dementia care. On the other hand, the challenges of cognitive assessment in non-literate or low-literate populations are profound, and, as discussed earlier, reasons for the poorer performance of minorities in cognitive assessment remain unclear. Poorer performance is apparent in non-verbal as well as verbal tests and is visible in even the most basic tests of mental status, such as the Mini-Mental State Examination. Part of the explanation for lower performance lies in the lower educational attainment of minority populations, since education is strongly associated with neuropsychological assessment. However, even when African Americans or Hispanics are matched with Whites of similar educational experience, performance of minorities is poorer, though differences are attenuated. The explanation may lie in poorer quality of education or lower literacy of minorities despite equivalent educational experience.

Physical Function

While ethnic and cultural minorities are more likely to report poorer physical function (such as need for help bathing or lifting groceries), physical assessment does not appear to suffer the same test biases as cognitive assessment. Still, major differences in strength, speed, dexterity, and sensory acuity have been reported for ethnic and cultural minorities. For example, in a New York City sample of elderly Whites, African Americans, and Hispanics, the groups did not differ in grip strength, as measured by a hand dynamometer. Only expected differences by age and gender were apparent. However, when compared to a sample of New Delhi elders, major differences were apparent. The Indian elders demonstrated only about half the grip strength of the Americans, even when the groups were matched by age, gender, self-reported disability, and disease status. Since expected differences were also evident in the Indian sample (women had lower grip strength than men, diabetics had lower grip strength than non-diabetics, etc.), the great difference in grip strength between American and Indian elders likely reflects lifelong effects of poorer nutrition, more challenging manual labor, poorer access to health care, and related factors.

Affect and Mental Health

Mexican Americans appear to be at greater risk for depressive symptoms than Whites in the same geographic region, and the prevalence of such symptoms is strongly related to degree of acculturation. The greater prevalence of poorer mental health (anxiety, depressive symptoms, poorer morale, panic syndromes) has been reported for a number of different ethnic and cultural groups in the United States. However, the difference in prevalence is likely due to the challenges of assimilating to a new and often very different society, and not to features of culture or ethnicity per se. Also, the status of mental health symptoms varies across cultures; for example, it is not clear that feeling anxious or loss of interest mean the same thing to a new immigrant from, say, Cambodia, and an elder American. Indeed, psychometric studies of depression measures suggest that assessment items do not travel well across cultures. Items that typically form a scale in American samples (such as dysphoria or somatic symptoms) do not correlate highly in non-American samples. This has led some investigators to conclude that depression may differ across cultural groups. Different psychometric properties for depression measures have been reported for Korean, Native American, and African American elders relative to White elders. How these differences in the experience of mental health symptoms may matter for mental health service use is another area in need of further research.

Relevance of Culture and Ethnicity for Health Promotion in Late Age

Ethnic and racial minorities are less likely to take advantage of preventive health services, such as vaccinations and cancer screening, even when they are available. Again, it is hard to know how much of

this difference in service use is related to aspects of culture (such as a different understanding of prevention in late life or differences in the degree to which people view health as a matter of personal agency or entitlement) and how much is related to the cultural insularity that characterizes many ethnic enclaves. Cultural insularity in this context refers to restrictions in access to health information related to culture, such as not speaking English, but also religious proscriptions against contact with mainstream culture, for example, watching television or reading English language newspapers. This kind of insularity may have an important significance for health in ethnic communities organized around religious belief. In an orthodox Jewish sample of older women in Brooklyn, New York City, the prevalence of mammography, Pap smears, and colorectal cancer screening was low compared to New York City women of similar age and education. Use of these preventive services was lowest in the orthodox women who reported least exposure to mainstream sources of health information. It is important that ethnic and cultural communities that wish to maintain traditions and yet participate in effective disease prevention and health promotion efforts mobilize community resources, perhaps in partnership with public health agencies, to develop appropriate delivery of information in culturally acceptable ways.

Summary

The older world in the making will be a multicultural older world, with the majority of elders living in developing countries but with greater numbers crossing borders and immigrating to the United States as well. Thus, recognition of ethnic and cultural differences is likely to become more important for understanding variation in aging and how best to address the needs of an aging world. As this brief article has shown, cultural and ethnic differences in aging pose challenges to assessment, treatment, and service delivery. By way of summary, we can now address the questions posed earlier.

How will provision of health care and aging services have to be modified to reach these ethnic minorities? Clearly, service providers will need to understand more about cultural differences to deliver care effectively. Ethnic and cultural minorities may not mean the same thing as a White elder when they report anxiety, they may have lower reserves of physical and cognitive ability even before they develop frank disability, their families may play a greater role in health management, and they may be more resistant to use of available long-term care services. Clinicians and other service providers will need to develop partners in ethnic and cultural communities, or better yet train minorities to deliver care.

To what degree will clinicians have to alter assessment of elder health and well-being in the face of this increasingly multicultural elder population? The challenges of assessing cognitive ability in a nonliterate or low-educated elder are clear. Similarly, culture-specific measures of mood, sensitive to reporting styles, will need to be developed in some cases if we are to target therapies to ethnic and cultural minorities. Other areas of old age experience, such as physical assessment or recognition of dementia, may be less influenced by culture.

What kinds of outreach or innovation in service delivery will be required to close the gap in outcomes between majority and ethnic minority aged populations? Evidence, summarized here, suggests that the gap in access to health services and in health outcomes is closing in the United States. Yet disparities continue to be large in some cases, such as between Whites and African Americans. The availability of an expanding universal health insurance system for the elderly has gone a long way in closing the gap in access. However, the gap in health outcomes is more difficult and remains a challenge for the future.

See also: Caregiving and Caring; Ethnicity and Minorities; Life Course.

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D

Death and Dying

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Glossary

Advance Directive – A document that instructs physicians on the type of treatment a person wishes to receive if unable to express his or her wishes at a later time because of impairment; the living will is an early type of advance directive.

Brain Death – A condition in which vegetative processes of the body persist although the capacity for thought, experience, and purposive behavior has been destroyed.

Coma – A state of deep unconsciousness from which the individual cannot be aroused but in which the brain may remain intact with the possibility of recovery.

Death Anxiety – A turbulent emotional state that may be aroused when people encounter a life-threatening situation or reminders of their mortality.

Dying – Process of physical decline that ends in death. This term emphasizes the person who is living through the process, as distinguished from the medical condition itself.

Hospice – An alternative to traditional medical care for dying people that gives highest priority to relief of pain and other symptoms (also known as the palliative care approach).

Life Expectancy – Statistical estimate of the number of years of life a person is likely to have remaining; can be calculated from date of birth or from one's present age.

Minimally Conscious State – Severe impair that is distinguished from coma or vegetative state by limited and occasional evidence of awareness.

Organ Transplantation – Removal of body parts from a person at death to restore function or save the life of another person.

Persistent Vegetative State – The continuation of vital body functions over a period of weeks, months, or even years despite the individual's lack of responsiveness (a condition that is often maintained through the use of a ventilator and/or other life support devices, but that may also exist spontaneously).

Terminal Illness – An incurable condition that will lead to a person's death within 6 months or less. The period immediately preceding death is known as the end phase.

Introduction

Death has become ever more patient in fortunate societies such as the United States. The addition of three decades to the average life expectancy since the turn of the nineteenth century has been achieved mostly by protecting survival of the young (*see* Life Expectancy). Coming later rather than sooner, death is now increasingly associated with long-lived people. The need for informed decision making regarding end-of-life issues has also increased with a growing population that has reached its 'three score and ten' and kept going.

New Questions about Death and Dying

"What is death?" is a classic question that has been much pondered by philosophers and theologians through the centuries. Today, the question has become, "When is this person dead?" Traditionally, this determination was made by observing the lack of respiration, pulse, and response to stimulation as well as by lowered body temperature (hypothermia). A person was considered to be 'dying' when vital functions were failing and his or her doctors conceded there was noting more to be done. This situation changed as a result of three related developments: (1) longer intervals between onset of illness and death, (2) life support technology, and (3) organ transplantation. Financial considerations are salient in all of these developments: medical care that

is prolonged and intensive runs up the expenses, and there are high stakes in the process of organ harvesting and transfer.

In the past, deaths often occurred after an acute illness or traumatic injury. People today are more likely to live with a life-threatening illness for months or years. The distinctions between 'chronic illness,' 'terminal illness,' and 'dying' are sometimes blurred. The terminology remains important because people are treated differently in subtle ways when defined as 'dying.'

Life support technology that maintains respiration and other vital functions has become increasingly available in technologically advanced nations. This technology has helped people recover from acute medical crises. More controversial is its use with patients who are unresponsive and who seem to have little or no chance of recovery. Much confusion surrounds the patient who is unresponsive or nearly so. The doctors may diagnose brain death, but family members may see a person who looks physically intact and who, in some cases, goes through a sleep–waking cycle, moans, and makes non-purposive movements. The absence of electrical activity and blood circulation in the cerebral cortex signifies the loss of capacity for thought, experience, and purposive behavior that led to the introduction of diagnosis of brain death. The situation is complicated by the fact that vegetative functions can persist if lower centers in the brain stem are still operating.

In recent years it has become more widely acknowledged that the diagnostic situation is even more complex. The patient might be comatose, a condition of deep unconsciousness but with the possibility of intact brain and full recovery. Alternately, the condition might be a transient vegetative state, the lack of mental activity having been caused by drugs, extreme cold, or an injury from which recovery is possible. Yet again, the patient might be in either a persistent or a permanent vegetative state (a judgment made when the condition is of long duration). In the less often discussed minimally responsive state, there are limited signs of awareness, suggesting that the underlying brain damage is not total. Perhaps the most harrowing condition is the locked-in syndrome, in which the patient is immobile and non-responsive – but is conscious and able to communicate through eye movements. (This condition is thought to be rare, but its actual incidence has not been firmly established.)

Differential diagnosis requires a high level of expertise. It is not surprising when people without such expertise and access express varying opinions about the status of the patient. Furthermore, opinions can be influenced by the perceivers' values and needs. Conflicting interpretations of the non-responsive patient's situation have often been resolved through discussion. Sometimes, however, they have led to widespread public involvement, including the highest reaches of the executive, legislative, and judicial branches of government. The controversy usually centers on the ethics of continuing or withdrawing life support for a person who is either dead or not dead, depending on the standards applied. The most widely publicized cases have invariably involved young women. This pattern might be taken as another example of age bias in life and death situations (*see* Ageism and Discrimination; Ethics and Euthanasia).

Organ transplantation has further intensified the question of how death should be defined and determined. Those with a stake in successful organ donations are inclined to define 'dead' so as to maximize the harvesting of organs at the earliest possible time. Those involved with the care of a non-responsive patient are inclined to favor more restrictive criteria. Two competent and well-intentioned physicians, then, may have different approaches to defining the same person as either alive or dead, depending on their goals and responsibilities.

The ordeal of grieving and mourning is complicated when the loved one appears to be not yet dead but no longer quite alive. The emotional stress on family and friends makes it difficult for them to carry out their other responsibilities (e.g., parenting, working). As much as they might cherish the patient, they may also feel the need to get on with their own lives, a need that seems in this situation to have been thwarted by medical technology (*see* Bereavement and Loss).

Attitudes and Their Consequences

Mainstream American attitudes have tended to marginalize elderly men and women. Unfortunately, elderly people are also subject to our society's aversive attitude toward dying and death. The risks of bereavement and terminal illness increase with advancing adult age, placing us in double jeopardy of rejection by a society uneasy with both aging and death. Widowed elders may be shunned even by their peers because they have been touched by death. A member of a widowed persons' support group explains: "First, most people don't know what to say to you, so they get tight and jittery around you. But second, and more important, they look at you and think, 'That could happen to me, too!' You just being there reminds them that death is real and husbands die and this could happen to them, too." Fortunately, peer support groups for bereaved people have

become more common in recent years (*see* Widowhood and Widowerhood).

People apprehensive about their own aging often project this negative attitude. For example, my walking companion noticed an elderly couple strolling by a lake. She confided, "I will never be an old woman. I will never let myself become dependent. I will never just sit around and watch the world go by. I will never die slowly and painfully. Let me assure you, I am being serious. One of these days, while I still have my health and independence, I will end my life. And I have it all worked out." This intelligent and robust woman in her early 50s described the specific method she would use to commit suicide. "I have seen plenty of old people," she added for emphasis, "so I don't intend to be one." Meanwhile, the elderly couple who had innocently provided the stimulus for this monologue continued to stroll around the lake, hand in hand. The woman who assumed that aging would be worse than death had not conversed with the couple and had no direct knowledge of their lives: she was a prisoner of the societal stereotype she had imposed on them – and on herself.

The most salient societal attitudes toward elders include the following:

1. Discomfort with one's own future status. American society encourages the development of a self-concept that does not encompass the entire life course. The 'I' who will face bereavement, grow old, and die is excluded from the sense of self. One may cling to the following scenario: "I will never grow old. And I will not be there when I die, because that person will be a stranger, not my real self."
2. Negative characterization of elderly persons and persons who have been touched by death. Elderly persons are assumed to be frail, lethargic, asexual, senile, incompetent, useless, and burdensome. Dying and bereaved persons are presumed to be depressed, bitter, and withdrawn. This negative attitude contrasts with the experiences of caregivers who have discovered that people bring many distinctive personal strengths into the later years of their lives. People who have entered the lives of elders in the role of caregiver or researcher often report that they have themselves received something valuable from the relationship.
3. Legitimization of avoidance strategies. Negative stereotypes provide justification for avoiding intimate contact. These justifications may be expressed in statements such as "It's better to avoid sensitive topics like, well, you know what." Under the surface of these propositions lies the anxiety of confrontation with those who remind us of our own unresolved problems with aging and death.
4. Communication, when it cannot be avoided, that is governed by special rules. When younger adults converse with elders they tend to use 'secondary baby talk,' a simplified speech accompanied by exaggerated intonations and facial expressions. Through this strategy, they attempt to restrict what the other person can say. Studies have repeatedly shown that most people try to keep a greater physical and social distance between themselves and those who are perceived as dying or grieving. Egalitarian give and take is replaced by 'down-talking,' in which the elderly, bereaved, or dying person is treated as inferior in terms of status, power, and value.

The convergence of negative attitudes toward both aging and death is consequential. For example, it is often assumed that the death of an elderly person is relatively unimportant. Little attention was given to the psychological, social, and spiritual needs of the dying person until the introduction of the hospice concept. Elders who reside in institutions are still likely to die alone, however, with sedation replacing companionship. This dismissive approach affects those who participate in the process. Staff members in nursing care facilities report feeling more depressed about their own future because they have seen repeatedly how the deaths – and therefore the lives – of elderly residents have been accorded little respect. This dismissive process also ignores the needs of those who loved and valued the deceased. Societal attitudes that legitimize turning away from the dying elderly person can therefore have long-term adverse consequences.

The death of an aged person is still the occasion for elaborate funeral and memorial observations in some societies, such as the Hmong, both in their homeland (Laos) and the United States. The rites of final passage affirm both the person whose life has just ended and the fundamental values of the group. By contrast, funeral directors continue to report that the general preference among Americans is for services that are brief and 'not too emotional.'

In planning the funeral and memorialization process for elderly people, there are often special circumstances to consider, such as the following:

- Conflicting ideas about the value and purposes of a funeral; generational differences within the family often are the source of dissension
- Unresolved family issues and grievances that are activated by the funeral process
- Uncertainty or conflict in deciding who should make the decisions
- Difficulty or inability of other aging family members to travel
- Financial hardship

Families that engage in open and ongoing discussion about life and death issues are more likely to avoid conflict, confusion, and regrets when the time comes to make these final arrangements.

Individual Orientations toward Dying and Death

We turn now to the elderly person's own view of dying and death.

Death Anxiety

Do we become more anxious about death with advancing age? Not necessarily. Elderly people most often report a decrease in death anxiety over the years. The most frequent explanation is that "I have had a life." A strong marriage, the nurturing of children and grandchildren, and a sense of having met one's responsibilities in all spheres of life are accomplishments that death cannot invalidate. Death anxiety scores generally are higher among young adults, who voice concerns about their plans and desires that might never come to fruition. People who are still searching for their personal identities and sense of worth are more likely to feel threatened about the possibility of a foreshortened future than those who have a firm sense of self, value, and accomplishment. Age, however, is only an indirect variable. Young adults can achieve a sense of living fully and well, and elderly adults can be burdened by a sense of disappointment, regret, and unfulfillment.

Another major contributing factor to reduced death anxiety in the later adult years is cumulative experience with losses and limitations. A person of 80 is unlikely to retain the 20-year-old's sense of invulnerability. Most people learn how to accommodate themselves to the changes that occur over a long life. A person may at first resent the need to acquire glasses or a hearing aid, but then utilize these devices to maintain quality of life. One elder observed: "I stopped being immortal a long time ago. I am in the flow of life, the flow of aging, we all are. This flow, this river delivers us into the great sea. That's life. That's just the way things are."

People who throughout their lives have depended on other people to cope with anxiety-arousing situations are likely to continue to do so when they are faced with death-related situations. This behavioral consistency is also likely for those whose preferred coping technique has been counterphobic (seeking out encounters with sources of fear, e.g., by taking extra risks with their lives), avoidance, or intellectualization. Problems arise when a preferred strategy for coping with anxiety is no longer available or effective. For example, a person who has characteristically bolted from difficult situations and relationships may discover that there is no easy way to escape from a failing body.

Some people do experience heightened death anxiety with advancing age. This is most likely to occur under four circumstances: (1) acute symptomatic episodes, (2) perceived lack of social support, (3) failure of coping strategies, and (4) fear of rejection or punishment by God. In a person with emphysema, for example, who is stricken by alarming episodes of respiratory distress, it is the increasing vulnerability to these episodes rather than age per se that heightens his or her death anxiety. People who feel alone and abandoned are also likely to experience death anxiety more often and intensely. Multiple and unremitting life stresses can overwhelm the individual's confidence and sense of security. A spike of death anxiety in such circumstances does not necessarily signify that the person's life is actually in acute jeopardy. Rather, death has become the symbol of one's feeling of helplessness and dissolution.

Elderly people tend to be more concerned about the manner in which they will die rather than the fact of death per se. Elderly men and women often express concerns about becoming helpless, dependent, and subjected to life support devices. Fears of disfiguration, pain, and clouded consciousness are voiced more frequently and with more intensity than fear of death. By and large, elders seem to come to terms with their mortality, whether through faith in God and survival, or through a philosophical acceptance. Many elders cherish each day's gift of life, neither seeking nor hiding from death.

Living through Dying

Denying the fact of terminal illness used to be a common strategy in the United States and many other nations. Bedside visitors would assure dying people that they would soon be up and around. Ironically, the dying person's hesitancy to share his or her thoughts was often interpreted as denial when it was actually a strategic maneuver intended to reduce the anxiety of family and friends who were themselves hesitant to face the facts.

Dying people also were deprived of reliable communication and social support because they were unwelcome reminders that medicine could not always work miracles. Furthermore, the dying person often suffered unrelenting pain and other stressful symptoms that were not well controlled by the prevailing customs of medical management. Restricted in communicational interactions, rejected as medical failures, and left to their suffering, terminally

ill people were hard-pressed to find comfort and value in the end phase of life.

This pattern of avoidance, suffering, and social isolation is now being transformed by two developments:

1. Death education and counseling. Academic courses and professional workshops on death and dying started to appear in the mid-1960s. The research of Herman Feifel exposed the cultural taboo on death, and the lectures and writings of Elizabeth Kubler-Ross encouraged professional caregivers and family to discuss these topics openly. Counselors willing and able to help people deal with dying, death, and grief have also become more available in connection with the death education movement.
2. Hospice and palliative care programs have proven a valuable alternative to traditional medical management of terminal illness. Compassionate and effective care of the dying person has become a higher priority. Those who select the hospice alternative – especially at a relatively early point in their terminal illness – are likely to benefit from improved techniques for controlling pain and other symptoms, as well as from the opportunity to live at home much of the time. The improved comfort and communication associated with hospice care enables dying people to draw more fully on their own resources and the resources of their most valued companions.

End-of-Life Issues and Choices

Elderly adults are becoming increasingly interested in learning about end-of-life issues and choices. As a woman in her late 80s observed, "I am still responsible for my life. I think I should take some responsibility for my death, too, don't you?"

It may be necessary first to overcome the resistance of adult children to discussing end-of-life issues. Often they need to be reassured that their parents or grandparents are neither depressed nor fragile. Rather, it simply makes sense to discuss death-related issues within the family, make the choices, and then go on with life. The alternative is to be overtaken by events and not have the opportunity to have one's preferences fulfilled. Many families are discovering that by confronting end-of-life decisions they are also becoming more aware of priorities and decisions for making the most of their own lives.

End-of-life decisions include distribution of personal assets, funeral and memorial arrangements, and choice of hospice or traditional medical care. Many experts believe it is the advance directive for health care that deserves the most attention. The current regulations and options evolved from the living will, which was introduced in 1968 as one of the first expressions of the nascent death awareness movement. The living will was intended as an instructive document for health-care personnel should a situation arise in which there was no reasonable expectation of recovery and the patient was too impaired to communicate his or her preferences. The living will requested that physicians administer medication to alleviate suffering, even if this would shorten the patient's life. However, physician were also asked to refrain from trying to keep the person alive by medications, artificial means, or 'heroic measures.'

The living will was received favorably by the American public. However, the document was not legally enforceable: health-care personnel were under no obligation to act in accordance with the instructions. Many physicians who sympathized with the idea behind the living wills hesitated to act upon them, out of concern that they might be accused of malpractice, or even homicide. Additionally, the language was too vague and the instructions too general to serve as guidelines in many situations (e.g., precisely what is 'artificial' or 'heroic'?). These problems were partially remedied as state legislatures passed bills that established some version of the living will as a legal document (often called 'natural death acts'). This was followed by a new generation of advance directives that encouraged the individual to be more specific. Every health-care institution that receives either Medicare or Medicaid reimbursements is now required to ask all clients about their preferences should a terminal illness arise. Patients must be informed of their rights to accept or refuse treatment and to provide their health-care facility with an advance directive if they so desire. The effectiveness of this regulation, however, depends much on the hospital's dedication to presenting the information in such a way that the patient understands the options and has a pressure-free opportunity to consider them. There have been numerous complaints about the manner in which the informed consent process has been carried out.

The major advance directive options (**Figure 1**) may at first appear similar, but the differences can be critical when guiding medical decision making during a crisis. An advance directive that is clear on these options is more likely to be honored by health-care personnel than the more ambiguous language of the original living will. Whether or not an individual intends to authorize an advanced directive, it is a useful learning experience to consider these options and become familiar with their implications.

Yes	No	Options
		1. I want all life-sustaining treatments to be discontinued if I become terminally ill and permanently incompetent.
		2. I want all life-sustaining treatments to be discontinued if I become permanently unconscious, whether terminally ill or not.
		3. I want all life-sustaining treatments to be discontinued if I become unconscious and have very little chance of ever recovering consciousness or avoiding permanent brain injury.
		4. I want to be kept alive if I become gravely ill and have only a slight chance of recovery (5% or less), and would probably require weeks or months of further treatment before the outcome became clear.
		5. I want to have fluids and nutrition discontinued if other life- support measures are discontinued.

Figure 1 Advance directive options.

Elderly adults who make the effort to learn about their end-of-life options are in a position not only to influence future events in their own lives, but also to serve as mentors for younger adults and as an insistent voice demanding that health-care systems give the attention that advance directives deserve.

See also: Ageism and Discrimination; Bereavement and Loss; Ethics and Euthanasia; Life Expectancy; Widowhood and Widowerhood.

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Decision Making and Everyday Problem Solving

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Glossary

Abstract Problem Solving – Problems that involve finding the correct solution to a novel task and that incorporate novel stimuli. Examples include concept learning, visual/spatial tasks, and search tasks.

Ecological Validity – A concern with the investigation of processes used in everyday life.

Emotional Salience – The degree to which an individual is emotionally involved in a problem situation.

Emotion-Focused Strategy – Solutions involving covert behaviors that manage or control emotional reactions such as positively reappraising a situation or passively accepting a situation.

Interpersonal Involvement – The degree to which social concerns underlie the context of a problem situation.

Personal Relevance – The degree to which an individual is personally affected by a problem situation.

Problem-Focused Strategy – Solutions involving self-initiated, overt behaviors that deal directly with a problem and its effects, such as taking direct action to alter a situation or seeking information or advice about it.

Problem-Solving Efficacy – The use of effective and adaptive problem-solving strategies.

Introduction

Empirical evidence based on traditional models of abstract problem solving and decision making demonstrates decline in performance as adults grow older. However, researchers have become increasingly dissatisfied with this theoretical and methodological approach as the sole means for assessing adult intellectual functioning. In response to these concerns, a growing body of research has emerged that assesses the skills and knowledge necessary for successful functioning in an everyday context. In contrast to research demonstrating a decline in abstract problem solving, problem-solving competence in adulthood and aging is maintained in socio-emotional or everyday types of situations. This is particularly evident when researchers consider the ways in which an individual perceives and structures the problem situation. In other words, problem-solving efficacy may not simply be a function of how many more 'correct' solutions an individual generates for a given problem. It may be more a function of (1) whether or not the problem reflects situations encountered in daily life, (2) whether or not the circumstances of the problem are personally meaningful or emotionally salient to the individual, (3) how the individual interprets, organizes, and restructures the problem space of the everyday situation, and (4) how adaptive a specific solution is given the individual's goals and context of living.

Approaches to the Study of Everyday Problem Solving

Concerns about Traditional Approaches to Problem Solving

Research examining age differences in abstract problem solving demonstrates more effective problem solving in college-aged and middle-aged individuals as compared to older adults. However, the majority of these studies constrain problem-solving ability to abstract tasks that have only one optimal solution (e.g., concept learning, abstract inferencing, and logical reasoning tasks). Problems that occur in our everyday lives are typically rich with context or individual-specific information that bounds the thoughts and actions of the problem-solver. Thus, context-free, abstract measures of problem solving may not be valid indicators of adaptive skills across multiple domains of adult functioning. Although understanding abstract problem solving is vital to the growth of our knowledge of age-related change in thought processes, measures of everyday cognition that attempt to capture the true lifestyle of individuals are also valuable. Focusing the microscope of vigorous study on the day-to-day tasks and struggles of all individuals can help to inform those clinicians, caregivers, and policy makers who are especially concerned with the well-being and independent functioning of senior citizens.

The Issue of Ecological Validity

One might expect that age-related decline in formal measures of reasoning would lead older adults to be less able to effectively function in their day-to-day activities. However, older adults report that their social reasoning about everyday matters has improved over time despite losses in other areas of cognition. Some researchers argue that a portion of the decline observed in older adults emerges because the skills that are necessary to perform abstract problem-solving tasks in the laboratory are not well practiced in middle-aged and older adults. Thus, a number of alternative approaches to investigating everyday problem solving have emerged, all with a common goal: to identify and measure types of problem-solving skills required for effective functioning in an everyday context during adulthood.

In pursuit of this goal, researchers improved the ecological validity of problem-solving tasks by incorporating more meaningful and realistic materials in their studies. A first approach was to change the content of traditional problem tasks to conform to content that is more relevant in adulthood (e.g., substituting strategies used to solve an abstract numerical problem with arithmetic strategies to select best buys in a supermarket). By improving the face validity of the tasks, it was assumed that the bias inherent in abstract problem-solving tasks would be removed. Although the typical age differences found in more traditional problem-solving studies were attenuated in studies conducted within this framework, a negative linear relationship between age and

problem-solving performance still remained. Also, simply varying the content of these abstract tasks does not eliminate the issue of which criteria are most suitable for judging problem-solving efficacy. It was argued that these tasks reflect only a cosmetic change to content and are still grounded in traditional abstract problem-solving (and youth-oriented) criteria. For example, they still demand a single correct solution and involve the same strategies used to solve astract problems.

Structural Characteristics of Everyday Problem-Solving Tasks

A more current version of the preceding approach structures everyday problem solving as a manifestation of underlying intellectual abilities. That is, problem-solving tasks have been designed to describe psychometric aspects of intelligence within problems that are experienced in daily life (e.g., understanding information on a medication label, using tax return forms). Problem-solving tasks grounded in this tradition tend to be well structured in that (1) the problem situation and the rules to be followed are defined by the experimenter, and (2) a single correct solution to the problem is required. An important but generally overlooked avenue in such tasks is the examination of goals and strategies used by individuals to solve ill-structured or ambiguous tasks. As a function of the social content inherent in these situations, ill-structured problems are unpredictable and are continually in transformation. The resulting ambiguity as to what defines these types of problems requires individuals to generate their own interpretation of a problem situation rather than rely on the structure imposed by others. In addition to multiple definitions of a problem space, there may be multiple solutions to ill-structured problems, all potentially effective depending upon the trade-offs one is willing to make. Finally, unlike traditional time-constrained abstract problems, it may take an extended period of time before one knows whether a decision to choose a particular solution strategy (among many potential candidates) will prove to be successful for an everyday problem (e.g., it may take months or even years to find out if one has chosen a compatible marital partner).

In concert with this approach, current research suggests that everyday problem solving across the life span is inherently interpersonal and thus has a strong socio-emotional component. This finding calls attention to the importance of emotions and other psychosocial factors involved in solving problems that emerge in adulthood. In fact, studies show that as adults grow older, their goals for solving problems become more concerned with other people, intimacy, and generativity. In sum, problems encountered in everyday life appear to be ill-structured, time-extended, and social in nature. These three characteristics of everyday problem situations help to stress the importance of taking a contextual perspective when assessing the efficacy of competing problem solutions.

A Contextual Perspective on Everyday Problem Solving

A contextual perspective enlarges the scope of everyday problem solving by considering the roles that cognitive, social, emotional, motivational, and cultural demands play in how individuals solve problems. For example, the goals of the individual relative to the circumstances (e.g., social demands) of the problem can influence how problems are managed. All of the these factors combine to have an effect on the appraisal and interpretation of a problem. They also influence the motivation behind an individual's decision to employ specific strategies to solve the problem.

For some problems (e.g., traditional well-structured, single-criterion problems), contextual demands act to drastically limit the number of responses that will lead to a successful outcome, so more traditional modes of problem solving are adaptive in this context. However, situations reflecting multiple criteria for potential solutions are more prominent in the problems of everyday living faced by older adults. There are several researchers who have attempted to specify these criteria from various theoretical perspectives.

For example, adaptive problem solving in an everyday context has been purported to entail (1) an awareness that the veracity of the solution to a particular problem is relative to differing perspectives and to the goals of the individual, (2) an awareness of the role of self in interpreting problems, and (3) a recognition that logical reasoning is embedded in a sociocultural matrix. In other words, individuals need to approach problems from a contextual perspective in order to exercise good judgment in problems reflecting uncertainty and ambiguity. From this framework, effective problem solving in an everyday context involves both the flexibility to adapt to the changing demands of one's environment and a system of organization to maintain continuous progress toward a desired outcome. It also suggests an 'openness' on the part of assessment criteria to judge the effectiveness of a problem-solving strategy as a function of the demands of the environment and the goals of the problem-solver in that particular context.

Adult Developmental Differences in Everyday Problem Solving and Decision Making

Criteria for Judging Strategy Efficacy

Following the precedent set by more traditional measures of problem-solving ability, quantitative assessments of strategy efficacy include the number of solutions generated, the number of steps needed to arrive at a solution, and the lack of redundancy in responding on test questions. In this case, both the best response and the criteria used to judge how effective an individual is at producing a solution have been determined by experimenters. It has been suggested that these types of criteria obscure qualitative differences inherent in a set of solutions. They do not take into account differences in the resources available to each problem-solver or qualitative differences in the algorithms used to solve problems.

Another criterion for judging problem-solving efficacy captures the individual's own perspective on problem-solving competence: individuals rate the efficacy of their own solutions. In this way, the criteria for problem-solving efficacy are determined by what the individual perceives to be effective given that she or he is living in the particular context in question. Researchers have also used a criterion group of judges to determine problem-solving efficacy (e.g., individuals' solutions are compared to the ratings provided by population-representative group ratings of expert adults). In essence, this approach provides a prototype (by means of the judges' efficacy ratings) of what is adaptive in a particular context. Solutions offered by participants in the study can be compared to this prototype. However, both self- and judge-perceived scales may be too global to delineate the qualitatively different form and content of an individual's solutions.

Given the importance of examining adaptive everyday functioning across the life span, emphasis has been placed on devising measures that are sensitive enough to capture possible developmental differences in how individuals structure reality and approach everyday problems. To these ends, problem-solving tasks may require the individual to generate her or his own interpretation of the problem situation. This approach considers qualitative differences in an individual-specific problem context and in the form and content of solutions. For example, some scoring systems may assess the type of strategies (e.g., problem-focused strategies, cognitive re-evaluations, emotional regulation) that are used to solve problems that emerge in particular domains of life. By contrast, other scoring systems examine the development of various modes of thought (e.g., self-oriented vs. other-oriented) that are important to reasoning through problem situations.

Age Differences in Problem-Solving Efficacy

In past research, examining age differences in problem-solving effectiveness involved asking young, middle-aged, and older adults to generate solutions for hypothetical practical problems (e.g., "When you open the refrigerator up, you notice that it is not cold inside, but rather it is warm. What would you do?"). Criteria for effective problem solving included the number of 'safe and effective' solutions as well as the number of 'self-initiated' solutions generated. Findings from examinations like this typically suggested that middle-aged adults outperform younger and older adults (who did not differ from each other). In other words, problem-solving performance would improve into middle adulthood and then decline. This trajectory, which resembles that found on measures of traditional intellectual ability, has also been found in a number of studies using psychometric measures of everyday problem solving.

The demonstrated decline in problem solving and decision making in older adults has been interpreted by some to reflect a biologically determined decline in the maximum potential of cognitive processing beginning after early adulthood. Indeed, such tasks are highly related to age-related decline on basic cognitive tasks. Although experience may compensate for this deficit during the earlier portion of adulthood, it is in the older adult years that the decline is sufficient to interfere with even frequently practiced abilities. In contrast to decline in everyday problem-solving ability, other researchers find either equivalent performance among younger, middle-aged, and older adults or linear improvement in problem-solving efficacy and decision making throughout the life span. However, different criteria for judging problem efficacy are employed in these studies. For example, in a number of studies, participants generated a solution to various problem situations (as performed in the previously described studies). In these studies, individuals rated the efficacy of their own solutions. Results indicated no age differences between young, middle-aged, and older adults when self-perceived problem-solving efficacy was assessed.

These findings are moderated somewhat by the relevance of problems to participants' lives. For example, when participants generated their own problems, equivalent self-rated problem-solving efficacy across age groups was found. However, when participants were responding to experimenter-generated

(i.e., hypothetical) problems, young and middle-aged adults provided higher ratings of self-efficacy than they did for their solutions to self-generated, personally relevant everyday problems. Interestingly, older adults viewed their solutions to both of these types of problems as being equally efficacious, indicating that the older participants felt that they were as able to reach successful outcomes in hypothetical problems as they were in problems that they actually face in real life.

In addition to this pattern of results for self-rated problem-solving efficacy, other studies have found improvements in problem-solving efficacy across the life span when comparing the preferred strategies of adult judges to adults of various ages. An Everyday Problem Solving Inventory was developed to assess practical problem solving in everyday situations. The inventory consists of six different content domains in which an adult might experience a problem situation, including consumer issues, home management, interpersonal conflicts with family members, conflicts with friends, conflicts with co-workers, and dealing with technical information. Possible responses were enumerated for each of these situations (including problem-focused action, cognitive problem analysis, passive-dependent behavior, and avoidant thinking and denial) and were evaluated by judges, ranging in age from 24 to 72, as to their potential efficacy. The inventory was then administered to adults ranging in age from 20 to 78 years. Examination of age differences revealed that effective performance on the problem-solving inventory (as defined by the judges) increased with age, whereas performance on more traditional problem-solving tasks declined after middle age. Interestingly, performance on the problem-solving inventory was not related to cognitive abilities, whereas traditional problem-solving tasks were related to cognitive abilities. Consistent with these expectations, studies have demonstrated that older adults are better than young adults at tailoring their strategy choices to specifically meet the demands of the issues that they are addressing (e.g., family, relationship, consumer problems). For example, researchers examining different styles of problem solving in adolescence through older adulthood found dissimilar patterns of results when contrasting participants' responses to instrumental (achievement-oriented) problems and to interpersonal conflicts. No age differences were found for problems representing consumer decisions and home management; all age groups tended to use more problem-focused strategies. In fact, younger adults opted for a problem-focused or cognitive analytic approach to all problems. Older adults, on the other hand, endorsed strategies that evinced an awareness of when to avoid or to passively accept a situation within interpersonal domains (e.g., conflicts with family or friends). Overall, older adults were more likely to endorse emotion-focused strategies than younger adults, who strictly relied on more problem-focused strategies. These results suggest that older adults may choose a diverse array of strategies to specifically target the contextual aspects (instrumental or interpersonal) of problems. Conversely, younger individuals preferred direct, problem-focused action. This was true even in situations in which it may have been advantageous to be more mindful of the complex emotions of all parties involved. It is also important to note that, despite research that suggests that older adults 'lack' the ability to engage in cognitively complex strategies, older adults were just as likely as young adults to endorse problem-focused and cognitive analytical strategies (as evidenced by a lack of age differences or increased use of these strategies). Although advancing age may be associated with declines in performance on timed tasks of cognition, such declines do not necessarily translate into impaired everyday problem-solving effectiveness.

In sum, it appears that everyday problem-solving measures can be critically influenced by the world from which the problems are derived – that of the experimenter versus that of the participant. What constitutes a good solution to a problem may depend on the criteria used to judge problem-solving efficacy (e.g., who is making such a decision, the experimenter or the individual who tried the solution and had to live with the consequences). Finally, although age does influence the types of problems that are volunteered, older adults are no worse than younger adults at solving everyday problems, especially those problems that tap into the social domain. In reality, older adults may compensate for declines in traditional forms of reasoning by carefully selecting how best to invest their cognitive, physical, and emotional capital so as to achieve the best possible outcome given the contextual demands of the problem.

Beyond Strategy Efficacy: Examining Strategic Behavior

In order to better understand qualitative differences in the strategies implemented by young and older adults when solving everyday problems, researchers have designed measures of decision making that allow for the systematic evaluation of online problem solving. These measures include tasks that ask young and older individuals to make decisions (e.g., choosing a new car, apartment, political candidate, or health insurance policy) after considering

information presented on a matrix (i.e., grid with information organized by features and choices). Information-processing strategies are assessed by keeping track of the number of times an individual reads a given piece of information, the time devoted to viewing each cell selected on the grid, and the sequence in which participants view information (e.g., scanning several features of a single automobile versus comparing several automobiles for a single feature such as fuel economy). Using these factors, researchers can get a sense of how an individual arrives at a decision. When presented with information on automobiles, both young and older adults required the same amount of time to choose an automobile. Young adults conducted exhaustive searches, looking at most if not all of the information about a single automobile before moving on to the next. Conversely, older adults reviewed the information so as to narrow their options. They first identified the features of automobiles that were most important to their decision, and then they compared the automobiles starting with the most important feature. Automobiles were ruled out based on whether or not they satisfactorily matched the demands of the older participant.

This difference in the information search strategies used by younger and older participants is often attributed to the limited cognitive resources of older adults. Many researchers feel that, given age-related declines in memory, older individuals must strategically minimize (i.e., satisfice) the number of pieces of information that they simultaneously store and manipulate. However, the older adults' strategic behavior might also be expected if the contextual environment of the task was different for them relative to young adults. For example, older adults might have more experience with purchasing automobiles and thus might have approached the decision with well-defined preferences in mind. Preferences or rules of thumb (i.e., decision heuristics) would allow older adults to select an automobile without examining all of the information on the grid.

Although an individual can inadvertently miss important information when an exhaustive search is not used, the result of a less comprehensive search can be just as positive if the outcome is subjectively appraised as satisfactory. In other words, the effectiveness of one's everyday decisions usually depends on the circumstances under which the decisions are made. For example, studies have shown that older adults may demonstrate equivalent or superior performance relative to young adults when asked to make practical financial decisions. When presented with an opportunity to choose between various consumer discount plans, older adults were more likely than younger adults to choose the plan that best suited their anticipated expenditures. By holding a personally defined preference, the decision heuristic served an adaptive purpose for older adults. Research examining how individuals weigh the pros and cons of choice-related options demonstrates that the degree of personal relevance of the decision alters how likely individuals are to engage in heuristic strategies. Also, when the decision is important to an individual, it elicits strong emotions. These emotions promote careful deliberation and, if unresolved, prolong the selection process so as to avoid regret. Interestingly, decisions that are particularly relevant to one age group may not be as relevant to others. Developmental theories of emotion (e.g., Carstensen's Socioemotional Selectivity Theory) suggest that what is important to an individual changes across the life span: with advancing age comes the desire to maximize emotionally relevant experiences and to minimize emotional setbacks.

Based on this prediction, young and older adults may place different values on the same aspect of a decision. For example, when choosing to rent an apartment, older individuals may place more value than younger adults on how close a given apartment complex is to the residences of their immediate family members. Similarly, when faced with a difficult decision wrought with negative emotions, older adults may be more likely than younger adults to delay the decision in order to avoid the regret associated with making a mistake. For example, a senior citizen who has recently retired may prolong making a decision about possible supplemental insurance policies for fear that the new policy will detract from his or her current policy. On the one hand, maintaining the status quo provides emotional benefits with a minimal investment of cognitive resources. On the other hand, delaying the decision could result in a less than optimal insurance policy. Current studies support the idea that the emotional content of a decision-making task can influence the amount of effort that older individuals devote to information processing. For example, older individuals have been found to remember chosen options as being more positive than the options that were forgone. Future research will tell us under what conditions it is adaptive to increase one's attention to emotional components of decisions and when it is not.

Factors Mediating Age Differences in Everyday Problem Solving

As mentioned earlier, age differences emerge in how an everyday problem is defined due to age differences in appraisals of the problem's context. Consequently,

researchers have sought to more clearly identify those aspects of a problem's context that may mediate age differences in everyday problem solving. Included among these factors are problem appraisal, interpersonal involvement, personal relevance, and emotional salience.

Problem Appraisal

Differences in strategy use for everyday problem solving are shown to be a function of age differences in the underlying interpretations of the problem or decision-making situation. Indeed, effective problem solving depends upon a realistic appraisal of the situation that matches or approximates the unfolding of events. Furthermore, there is a need to examine differences in problem appraisal between younger and older adults in order to understand better strategy use and the potential adaptive nature of such age differences.

For example, one study found that younger and older adults differed in their appraisal of problems as a function of the type of situation and relevance to their everyday functioning (e.g., a visit to the doctor's office and problems arising at a dinner party). On the one hand, older adults interpreted the doctor's office problems as external-social (i.e., something to do with the social circumstances rather than themselves). On the other hand, older adults viewed the dinner party problem more as internal-cognitive (i.e., something to do with their decision making). Younger adults interpreted both problems as internal-affective (e.g., they attributed the problem to their personal emotions). In addition, the way in which both age groups interpreted the problem influenced their subsequent selection of problem-solving strategies. Some researchers propose that mature thinking involves the redefinition of the problem space by accepting inherent uncertainties and resolving them. Similarly, other researchers suggest that this interpretive process in adulthood is characterized by an increased awareness of self as interpreter or the ability to consider multiple perspectives in reasoning tasks of an interpersonal nature. A number of developmental changes in how individuals structure reality and approach a problem situation (e.g., awareness of self as interpreter, cognitive representations of events, cognitive appraisal) have been identified. However, more research is needed to link these changes in problem appraisal with subsequent selection of problem-solving strategies.

Interpersonal Involvement

Researchers interested in everyday cognition have also found that older adults interpret everyday problems differently than younger adults in that they focus on interpersonal concerns of the problem. Some studies have shown that early on in adulthood, interpersonal goals emerge and become as important as competence goals. From middle adulthood to old age, individuals tend to report that the problems that they face occur in more social domains. Problems are more widely distributed across several domains (as opposed to being primarily related to schooling or one's career). Also, across age groups, people who face problems in interpersonal domains (e.g., family and romantic relationships) tend to use strategies that involve regulating and including others in the solution process.

Consistent with these trends, another study on how adults solve interpersonal problems displayed similar results. In non-romantic relationship situations, adults of all ages endorsed problem-focused strategy combinations geared at improving the circumstances of the problem for other individuals involved in the conflict. For romantic relationship situations, however, older adults were more likely than young and middle-aged adults to first try to regulate their own emotions (e.g., by hiding how they truly felt). Conversely, the younger age groups were more likely to first carry out some active problem-focused strategy to deal with the problem (e.g., confront their cheating spouse or pack their bags and move to their mother's house). Although there are age differences in the strategies used to cope with interpersonal problems, it is possible that the preferred strategies of each age group are equally as effective. It is important to remember that, when faced with a standard (empirically derived) hypothetical problem, younger and older individuals each might bring distinct contextual perspectives to the situation. For example, although individuals of all ages would be angry if their spouse were unfaithful, older adults may place more importance on emotion regulation than younger adults because of the immense quantity of resources that they have already invested in the relationship. Based on these studies, young and older individuals differ in how they deal with interpersonal problems. As is discussed later, the emotional nature of interpersonal problems is an important component of these age differences.

Personal Relevance

Besides being influenced by the emotional nature of everyday problems, strategy selection in everyday problem situations is also influenced by the importance or relevance of the problem as seen through the eyes of the problem-solver. Personal relevance, whether it takes the form of age relevance (i.e.,

problems characteristic of the participant's age group) or self-generated problems (i.e., problems described by individuals when asked to discuss issues that they are dealing with), appears to affect whether or not age differences in problem-solving efficacy will also be observed. Although the findings from studies are mixed, older adults seem to be more influenced by perceived relevance of individual problems. First, a number of studies reveal that older adults perform better on tasks reflecting personal relevance and familiarity than on hypothetical tasks. In other words, young and middle-aged adults outperform older adults on hypothetical problems, whereas no age differences emerge when problems were self-generated. In addition, in contrast to younger adults, older adults rate their solutions to self-generated problems as being equally as effective as their solutions for experimenter-generated (hypothetical) problems. As mentioned earlier, older adults may feel more efficacious because they approach problem situations equipped with a lifetime of experience from which they may select those strategies that have proven to be successful for them in the past.

When age-relevant problems were developed for individuals of varying age (e.g., problems relevant to young, middle-aged, and older adults), young and middle-aged adults performed best on problems relevant to their own age group, whereas older adults did not vary as a function of the age relevance of the problems. Some argue that experience and familiarity may compensate for deficits in everyday problem solving. Others suggest that older adults compensate for age-related deficits by taking steps (e.g., heuristically relying on past successful strategies) to minimize the effort that is needed to generate the most efficacious solution to problems. However, life experience is a difficult variable to measure. More research is needed to directly examine the roles that experience and heuristic decision-making strategies play in everyday cognition. At this point it can be argued that familiarity and personal relevance mediate age differences in everyday problem solving. In other words, familiar problems tend to be managed effectively in a similar fashion across age groups.

Emotional Salience

Earlier in this article it was noted that one of the defining characteristics of everyday problem solving was the interpersonal nature of problem situations encountered in everyday life. In addition, a common finding among studies on age differences in problem-solving strategies is that changes in strategy preference are most evident in interpersonal situations that characteristically embody emotional and psychosocial factors. The apparent role that emotion plays in how an individual construes a problem (particularly in an interpersonal context) and, in turn, adopts a problem-solving strategy has recently been addressed in the problem-solving literature. For example, with increasing age, individuals engage in more mature social reasoning (e.g., increased relativistic thinking) in emotionally laden situations; older adults with high affective intensity demonstrate more dialectical thinking; higher levels of ego maturity involving emotional regulation and openness to affective experience relate to more mature coping and problem solving; older adults make more complex causal attributions in problem situations that are high in emotional salience; and emotional salience plays an important role in age differences in coping with stress.

In one study, emotional salience of problems (ranging from low to high) was found to be a critical determinant of the degree to which individuals reported a particular problem-solving strategy. In low and high emotionally salient situations, there were no age differences in the use of instrumental and proactive strategies. However, in high emotionally salient situations, older adults endorsed more passive-dependent and avoidant strategies than either young or middle-aged adults. These findings support the premise that the responses of older adults are related to the nature of the problem situation. Like the other age groups, older adults used more problem-focused strategies in instrumental and less emotionally salient task situations (e.g., returning defective merchandise). When the situations were more emotionally salient (e.g., moving to a new town, taking care of a parent), older adults used more emotion regulation strategies (e.g., suppressing feelings, not trying to alter an uncontrollable situation).

Similarly, a number of studies have shown that, in general, older adults use more emotion-focused styles of coping than younger adults. For example, older adults report fewer negative emotions, and they appear to be better equipped with cognitive problem-solving skills for negative emotions. When the problem situation is appraised as uncontrollable, older adults use more emotion-focused coping than younger adults. Finally, a life span developmental perspective has been proposed with respect to emotional regulation. In the latter half of the life span, individuals find emotional aspects of information more salient. In addition, older adults prefer to focus on the emotional potential in interpersonal relationships. In contrast, young adults do not focus as much on the emotional aspects of information presented.

In interpersonal relationships, they focus more on the information- and stimulation-seeking potential.

Recent studies are consistent with this hypothesis for life span developmental shifts in the implementation of emotion regulation strategies. When young, middle-aged, and older adults were asked to describe the strategies that they used to solve self-generated problems that they experienced with family members, middle-aged and older adults were more likely to report the use of emotion regulation strategies. Interestingly, middle-aged adults used more proactive forms of emotion regulation, whereas older adults used more passive strategies to control their emotions. These results suggest that older adults, when faced with emotional problems that involve others, are more likely to have an internal focus to their emotion regulation. Given their goal of maximizing positive affect, older adults may choose to use passive forms of emotion regulation in order to purposefully maintain the emotional meaningfulness of the relationships that they share with their closest family members. Further support for this hypothesis is found in studies that demonstrate that older adults are less likely to express their anger when coping with a highly emotional problem that they are having with a friend. In stark contrast to the traditional decline in reasoning that is often associated with advancing age, the affective-oriented goals and strategies used by older adults in interpersonal everyday problems portray them to be more complex, flexible, and emotionally mature than one might otherwise assume. Evidence for adulthood changes in the appraisal and regulation of emotion stresses the importance for future research to continue to examine everyday problem solving within an emotional context.

Conclusions and Implications

In conclusion, traditional problem-solving measures that are relatively abstract, are low in ecological validity, or come from a more psychometric tradition demonstrate decreased problem-solving and decision-making ability with age. Such developmental/age differences seem to emerge only on measures that draw upon information processing/mechanistic or intellectual abilities. However, with tasks of high emotional salience, ambiguity, and ecological validity, developmental differences have been documented that are related to qualitative changes in the way the individual perceives their problem-solving efficacy and structures everyday problems.

Therefore, in order to attain a more complete picture of developmental variation in problem solving, both research perspectives are needed. We must be able to differentiate (1) when age differences are due to a production deficiency or a genuine regression on the part of older adults and (2) when these differences can be attributed to discriminative and volitional choices in problem-solving strategy. Developmental differences can exist concurrently in that we see decline in abstract and psychometrically tested problem-solving ability while also finding increased sophistication in the appraisal of problem contexts and in the approaches used to solve real-world problems. Both types of developmental changes can exist in parallel; they may even complement each other.

See also: Consumer Behavior; Information Processing/Cognition.

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Delirium

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Glossary

Delirium – Characterized by sudden onset of impaired attention, disorganized thinking, or incoherent speech.

Delirium Room (DR) – A delirium intervention consisting of a specialized four-bed room that provides 24 hour nursing care and observation by at least one nurse in the room and that is completely free of physical restraints.

Introduction

Delirium is a medical diagnosis often referred to by clinicians as an acute change in mental status. Summarizing the *Diagnostic and Statistical Manual of Mental Disorders,* 4th edition, text revision (DSM-IV) criteria for making the diagnosis, delirium is characterized by a sudden onset of impaired attention, disorganized thinking, or incoherent speech. The patient usually has a clouded consciousness, perceptual disturbances, sleep–wake cycle problems, psychomotor agitation, or lethargy, and is disoriented.

Delirium is a dangerous diagnosis because it is common in various health-care sites, it is commonly missed, and it is associated with serious adverse outcomes such as loss of physical function and mortality. The comprehensive approach to delirium involves awareness, diagnosis (knowing how to differentiate between delirium and dementia), evaluation (identifying and treating the underlying causes of delirium), prevention, and management. Typically, the underlying causes of delirium are multifactorial and can be remembered using the mnemonic DELIRIUMS. Examples of prevention interventions include a multicomponent intervention with protocols targeting risk factors to prevent the development of delirium and a geriatric consultation service for patients with hip fracture. An example of a management intervention is a specialized four-bed room that provides 24-h nursing care, called the delirium room. Physical restraints should not be used in patients with delirium, and rarely should pharmacological restraints be used.

Definition and Types of Delirium; Prevalence and Incidence for Various Sites and Situations

According to the DSM-IV, delirium is characterized by a sudden onset of impaired attention, disorganized thinking, or incoherent speech. The patient usually has a clouded consciousness, perceptual disturbances, sleep–wake cycle problems, and psychomotor agitation or lethargy and is disoriented. Although the definition and thus diagnosis of delirium is based on the DSM-IV, it should be considered a medical diagnosis because one of the other diagnostic criteria is that there is evidence by history, physical, or

laboratory findings that the delirium is caused by the physiological consequences of a medical condition, an intoxication substance, a medication use, or a combination of these.

Most studies have agreed that there are two types of delirium: hypoactive and hyperactive. Patients may also have a combination of the two types. Using the available DSM criteria at the time, studies have found delirium in up to 22% of older patients on admission to the hospital and in up to 31% of older patients while hospitalized. Prevalence rates for confusion of any kind during admission have been found to be even higher.

In most studies, surgical patients have been found to have higher rates than medical patients. Postoperative rates were highest among coronary artery bypass graft patients, ranging from 17 to 74%, and rates among orthopedic surgical patients ranged from 28 to 53%. Studies of urologic patients found lower rates, from 4.5 to 6.8%. Anesthesia agents should not be blamed for these high rates, as several studies have found that the route of anesthesia (general, epidural, spinal, regional) was not associated with the development of delirium.

One of the sites with the highest rates of delirium is the intensive care unit (ICU). Rates as high as 80% have been found. For years, this problem has inappropriately been called ICU psychosis or sundowning, and has been considered inevitable and unpreventable, which may partly explain the high non-recognition rates of 66–84%. However, research has shown that delirium in the ICU is similar to delirium at other health-care sites (with associated poor outcomes), and clinical practice guidelines from the Society of Critical Care Medicine now recommend monitoring for delirium among all ICU patients.

Data from postacute care facilities (such as subacute care facilities, skilled nursing facilities, rehabilitation centers, and long-term care facilities) have shown that patients are discharged from acute hospitals with persistent delirium, and delirium at these sites persists for an extended period of time. One study found that 72% of 214 nursing home patients who were hospitalized still had delirium at the time of discharge back to the nursing home, and the delirium persisted for 55% of the patients at 1 month and 25% at 3 months. In a large study of more than 80 postacute care facilities using the Minimum Data Set (MDS) to identify patients with any delirium symptoms, a prevalence rate of 23% was found on admission, and 52% of these patients still had symptoms of delirium at 1 week follow-up.

Two studies that looked at point prevalence within nursing facilities discovered a similarly high rate of delirium, 14% of 324 long-term nursing home patients in one study and 33% of 74 patients in the other.

At least two reasons have been proposed to explain high prevalence rates at various sites. One reason is the higher occurrence of the hypoactive type of delirium compared to the hyperactive. The other reason has to do with patients who have subsyndromal delirium, in which patients meet only some of the criteria for delirium. This type should still be considered serious, as at least one study has shown intermediate negative outcomes when compared to delirious patients and patients without delirium.

Associated Adverse Outcomes

Delirium is one of the most serious diagnoses patients can have or develop. However, it has been reported that it is not identified in 32–66% of the cases, by either nurses or physicians. Hospitalized older persons with delirium compared to those without delirium are more likely to have hospital complications, loss of physical function, increased hospital length of stay, increased discharge to a long-term care facility, and even a higher mortality risk. Mortality rates for hospitalized delirious patients have been reported to be 25–33%, as high as mortality rates for acute myocardial infarction and sepsis.

Even when adjusting for factors such as older age, underlying cognitive impairment, severe acute and chronic illness, and functional impairment, delirium has been found to be independently associated with poor outcomes in most studies.

Associated adverse outcomes among delirious ICU patients have shown prolonged ICU stay, prolonged hospital stay, and increased mortality compared to patients without delirium. Data from postacute facilities have also shown associated adverse outcomes, related to loss of physical function and mortality.

Risk Factors

Numerous risk factors for the development of delirium have been identified. Risk factors can be external (environmental) or internal (depending on the status of the individual). A non-exhaustive list includes underlying dementia, recent surgery, dehydration, renal insufficiency, multiple medications, inadequate pain relief, indwelling urinary catheter, and physical restraints. The most important of these is probably an underlying dementia, which may have to do with the underlying neuropathophysiology of delirium.

Many hypotheses have been proposed, but to date, it is not clear exactly which or how many mechanisms are responsible for the clinical presentation.

Some hypotheses include abnormalities in neurotransmitter systems, vascular mechanisms, and neuroendocrine/immune mediation (e.g., cytokines).

The Comprehensive Approach to Delirium

Since delirium is a multifactorial problem, a multifaceted approach is warranted: (1) awareness: be aware of how commonly delirium occurs and where it occurs, and get others involved in the care of the older persons to do the same; (2) diagnosis: know why it is important to differentiate and how to differentiate between delirium and dementia; (3) evaluation: identify and treat the underlying causes of delirium; (4) prevention: implement strategies or care systems that can prevent delirium; and (5) management: manage patients who develop delirium.

Awareness

Since delirium is so common, and because there are so many risk factors for the development of delirium, health-care sites should consider screening for delirium. Several validated screening tools exist. A few examples of hospital tools are the Clinical Assessment of Confusion A, the Confusion Rating Scale, and the NEECHAM Confusion Scale, which were developed primarily for nursing. The Confusion Assessment Method (CAM) was developed for use by trained nurses and physicians. The CAM-ICU has been validated in ICU patients. The NEECHAM and a Visual Analog Scale for Acute Confusion have been validated in long-term care patients.

The use of the term delirium by health-care professionals in acute care and postacute care may increase awareness. Last, incidence rates and outcomes associated with delirium should be monitored (that is, they should become quality of care measures) at all sites where delirium occurs.

Diagnosis

One of the most important steps in diagnosing delirium is to realize that delirium is not dementia. Although delirium can arise during the course of dementia, the two are worth differentiating because most types of dementia have a progressive downhill course, whereas delirium is reversible most of the time. A mislabeling, or lack of differentiation between these two diagnoses, is thought to be the reason why delirium is missed by physicians at rates as high as 32 to 66% and by nurses up to 69% of the time. Misdiagnosis or late diagnosis may also partly explain why delirium is associated with adverse outcomes. **Table 1** details some of the differentiating characteristics between delirium and dementia, based on DSM criteria. One of the criteria not listed in **Table 1** is that delirium must occur in the context of a medical illness, metabolic derangement, drug toxicity, or withdrawal.

An altered level of consciousness (LOC) is useful in differentiating delirium and dementia because even if the patient's baseline mental status is unknown, one can still determine whether the patient's LOC lies toward the agitated or vigilant side of the spectrum of LOC or toward the lethargic, drowsy, or stuporous side of the spectrum.

Although disorientation can occur in both delirium and dementia, the key in distinguishing delirium from dementia is how the patient answers orientation questions. The delirious patient will often give disorganized answers, which can be described as rambling or even incoherent.

Acute onset and fluctuating course are two of the hallmarks of delirium. This information is usually obtained by close caregivers (family or nurses). The term subacute is used to emphasize that subtle mental status changes can be overlooked by caregivers. Over a period of many days, the patient may appear to be slowly declining mentally due to the underlying

Table 1 Characteristics of delirium versus dementia

Characteristic	*Delirium*	*Dementia*
Consciousness	Clouded Decreased or hyperalert	Usually alert
Orientation	Disorganized	Disoriented
Course	Fluctuating	Steady slow decline
Onset	Acute or subacute	Chronic
Attention	Impaired	Usually normal
Psychomotor	Agitated or lethargic	Usually normal
Hallucinations	Perceptual disturbances May have hallucinations	Usually not present
Sleep–wake cycle	Abnormal	Usually normal
Speech	Slow, incoherent	Aphasic, anomic difficulty finding words

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dementia. If left unchecked, the initial delirium may impair other necessary functions, leading to further medical problems, such as dehydration and malnutrition, further complicating the delirium. This snowball effect explains in part why the etiology of delirium is typically multifactorial. Thus, if it is unclear how long the change has been occurring, patients should be put in the category of delirium and an evaluation should be done.

Attention may be especially helpful if the patient's baseline mental status is not known. During history taking, patients may have difficulty maintaining or following the conversation, perseverate on the previous question, or become easily distracted. Attention can also be tested with cognitive tasks such as asking the patient to say the days of the week backward, spell a word backward, or perform other mental tasks that require focus and attention.

Psychomotor agitation or lethargy, hallucinations, sleep–wake cycle abnormalities, and slow or incoherent speech can all be seen in patients with delirium, but these features are not necessary for the diagnosis.

Evaluation

In general, the medical evaluation of patients who are thought to have delirium includes considering all possible causes, proceeding cautiously with appropriate testing, and keeping in mind that delirium is usually caused by a combination of underlying causes.

After a history and physical is performed, which includes obtaining details from anyone considered a caregiver (e.g., family, nurse's aide) and a thorough medication list, the mnemonic DELIRIUMS can be used as a checklist to cover most causes of delirium (**Table 2**).

Drugs are one of the most common causes of delirium. Although drugs with anticholinergic properties are the main offenders, since neurotransmitters involved in delirium go beyond the cholinergic system, a broader approach is warranted. Three general guidelines for the comprehensive approach are as follows: (1) drugs that have any central nervous system activity should be considered deliriogenic; (2) drugs that have recently been started or were started coincidently with the onset of cognitive changes may be the offending agents; and (3) almost any drug has the potential to cause cognitive problems.

Examples of the more common offenders are noted here to give the reader a sense of the preceding guidelines. Although many older reports did not discuss strict delirium criteria, or such criteria were not commonly used, their use of terms such as hallucinosis, paranoia, delusions, psychosis, general confusion, aggressiveness, restlessness, and drowsiness is still useful as they might indicate the presence of delirium due to these drugs. Thus, the following descriptions use these terms when the original reports used them, instead of the recommended term delirium.

Antiparkinsonian drugs probably cause delirium due to a tip in the tenuous balance of the neurotransmitters dopamine and acetylcholine, both implicated in the pathophysiology of delirium.

Although older short-acting antispasmodics (for urinary incontinence) have more of a potential to cause delirium, newer sustained-release agents have been reported.

Motility agents (of which metoclopramide is an example) have peripheral and central antidopaminergic properties. Reported mental status side effects include restlessness, drowsiness, depression, and confusion.

Since psychiatric medications are centrally acting, these are commonly targeted first as offenders of delirium. However, since psychiatric illnesses, especially depression, need to be treated, it is worth noting some of the reports of drug side effects in this area.

Tricyclic antidepressants (TCAs) can cause delirium, with an overall incidence ranging from 1.5 to 20%. The highest rates seem to be among older previously cognitively impaired and medically ill patients. Some TCAs are not as anticholinergic as others (e.g., desipramine) so that the risk of delirium is not an absolute contraindication to their use.

Serotonin selective reuptake inhibitor (SSRI) antidepressants have a much safer side effect profile compared to the TCAs as far as delirium is concerned. However, one of the main side effects of SSRIs, hyponatremia, can present as delirium in older persons. This has been reported with fluoxetine, fluvoxamine, paroxetine, and sertraline. Most reported cases seem to point toward drug interactions as a plausible cause.

Table 2 The multifactorial causes of delirium

D Drugs
E Emotions[a]
L Low O_2 states (hypoxic injury such as myocardial infarction, stroke, pulmonary embolus)
I Infection
R Retention (of urine or stool)
I Ictal (seizures)
U Underhydration/undernutrition
M Metabolic
(S) Subdural

[a] Depression is considered in the differential diagnosis of patients presenting with some features of delirium, although is not a cause of delirium.

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Benzodiazepines (BDZs) were introduced in the 1960s and are one of the most widely used psychoactive drugs. Unfortunately, their use is highest among the elderly. In one study of more than 400 hospitalized patients, age 58–88 years, who had normal Mini-Mental Status Examination scores on admission, use of BDZs was associated with a relative risk of developing cognitive impairment of 3.5 (95% CI; 1.4–8.8). Postoperative use of BDZs has also been found to increase the risk of delirium.

Antipsychotics can cause delirium. In one study of patients who were transferred from the psychiatric ward to a medical ward because of delirium, 31% of the cases were due to low-potency antipsychotic agents. Whether the antipsychotic prescribed is considered a typical antipsychotic or an atypical antipsychotic, the clinician needs to keep in mind that none of these drugs has pure mononeurotransmitter activity. Rather, they have varying degrees of activity, either agonist or antagonist to many of the neurotransmitters implicated in the pathophysiology of delirium, such as dopamine, acetylcholine, serotonin, and histamine. Thus, like other geriatric psychiatric medications, antipsychotic drugs can and should be considered a potential cause of delirium. Patients with Lewy body dementia have an increased sensitivity to neuroleptics.

The neuroleptic malignant syndrome is classically described as a triad consisting of fever, elevated creatinine kinase enzymes, and confusion. However, some authors believe that a variant, or rather a clinical spectrum, of the neuroleptic malignant syndrome can be seen in which patients may have only one or two of the triad features and may have only a small degree of these features. For example, patients may have subtle confusion and muscle rigidity, which is intermittent but only mild, or no elevation of creatinine kinase enzymes.

Narcotics can be used safely in older persons with little risk of developing delirium, but a few important details need to be remembered. Meperidine is particularly risky in older persons, likely due to the anticholinergic activity of its active metabolite normeperidine. The main problems associated with the use of narcotics and delirium are usually related to toxicity, overuse, or overdosage in patients with impaired hepatic or renal function, or stopping the narcotic abruptly.

Muscle relaxant is a misnomer because these medications act centrally in the brain, not locally at the muscles. Some of the commonly used muscle relaxants include cyclobenzaprine, methocarbamol, and carisoprodol and have been reported to cause delirium.

Seizure medications have been reported to cause varying types of cognitive impairment including drowsiness, agitation, depression, psychosis, and delirium. The cognitive impairment is thought to be related to serum levels, but clinicians should keep in mind that most anticonvulsants are protein bound, and if the patient's nutritional status is poor then there is potential that the amount of free drug will actually be higher than what is measured by the serum level.

For patients who present with delirium or for patients that are at risk for delirium, the general guidelines in **Table 3** can be used concerning medication management.

The E in the DELIRIUM mnemonic stands for emotions and reminds the clinician that depression, although not considered a cause of delirium, should be in the differential diagnosis of patients who present with features of delirium. This is because depressed patients can have psychotic features as well as other symptoms similar to patients with delirium such as disorganized thinking or psychomotor lethargy.

Low O_2 (oxygen) states in the mnemonic should highlight to the clinician that older patients with hypoxic injuries to the heart, lung, or brain (for example, myocardial infarction, pulmonary embolism, or stroke) can present with delirium. It could be said

Table 3 General guidelines for medication management in patients with delirium or at risk of developing delirium

1. Stop unnecessary drugs until the delirium has resolved, then reevaluate the necessity of these drugs once the delirium has resolved.
2. Use non-pharmacological interventions whenever possible instead of a medication.
3. Do not treat vague symptoms with a medication (for example, do not routinely give H2 antagonists for vague gastrointestinal complaints).
4. Include an assessment of OTC medications as potential offenders.
5. Evaluate all drugs for drug–drug and drug–disease interactions.
6. If a drug is started, decide on the duration of how long that drug will be used. The old rule of start low and go slow needs to be expanded to start low, go slow, and know when to stop.
7. The justification for prescribing medications should be based on therapeutic reasons and not preventive reasons until the patient is no longer at risk for delirium or the delirium has resolved.
8. Do not treat adverse effects of drugs with another drug unless completely necessary (as may be the case with long-acting narcotics and laxatives).

that delirium is as serious as a heart attack, because older patients who are delirious may actually be having myocardial ischemia. Whether it is because patients cannot tell clinicians about chest pain because of the delirium, or whether there exists a cardiocerebral syndrome in which the stress of the myocardial infarction affects the adrenergic system, causing a stress on the balance in the central nervous system, if an older patient is delirious, myocardial infarction should be in the differential diagnosis.

Not only are patients with stroke at risk to develop delirium as a complication of the stroke or the underlying comorbidities associated with the stroke, but delirium also may be the presenting feature of some stroke patients.

Infections are one of the most common underlying causes of delirium among older people. The most common types of infections that cause delirium are urinary tract infections and respiratory infections. However, subtle infections such as cholecystitis and diverticulitis should be considered part of the differential diagnosis if other clues point toward this diagnosis. Although meningitis should be considered, it is not clear whether or not cerebrospinal fluid analysis is warranted in the initial workup of delirious patients without other symptoms that point toward a central nervous system infection.

One of the most common nosocomial infections for older patients is urinary tract infections because of the use of indwelling urinary catheters. Given this risk, indwelling urinary catheters are not indicated for urinary incontinence or urinary retention that can be managed with straight intermittent catheterization and should not be used to monitor input and output unless this monitoring is critical for decision making and outcomes related to this parameter.

Retention of urine causing delirium has been well reported in the literature under the term cystocerebral syndrome. The original report was of three cases, all older men who became acutely agitated and near mute. All three patients had large volumes of urine in their bladder, and in all three patients, the agitated delirium resolved within a short time after emptying the bladder. One of the best ways to quickly evaluate for urinary retention is with a handheld bladder ultrasound. Although these have a fairly high initial cost, cost savings from the reduction in use of straight catheterizations may help balance this issue.

Retention of feces as a cause of delirium has not been reported in the literature. However, since older patients are at risk for fecal impactions for multiple reasons, clinicians should be suspicious of this problem when the delirium is of the lethargic type.

Ictal states are a rare cause of delirium and are not difficult to diagnose clinically for patients with tonic clonic seizures. However, complex partial and simple partial make up over half of the seizures in patients over 65 years. Also, absence seizures may go unnoticed to caregivers and may only seem to have fluctuating mental status changes. Although an EEG is not indicated in the initial medical evaluation of delirium, it should be considered when the pertinent history is obtained.

Underhydration should remind the clinician that dehydration can be one of the underlying causes of delirium. It should also be considered a risk factor for developing delirium. Although there are several circumstances in which an elevated blood urea nitrogen (BUN):creatinine ratio may not truly indicate dehydration, there are data to suggest that a ratio of greater than 17:1 puts patients at risk for delirium.

Undernutrition or malnutrition is considered an underlying cause of delirium related to the issue of medications that are protein bound. Patients who are malnourished may have lower protein stores, and thus protein-bound drugs will have a higher free concentration that puts the patient at risk for delirium. Other proposed relationships between malnutrition and delirium that have yet to be fully elucidated include those mechanisms looking at cytokines.

Metabolic abnormalities that cause delirium are not difficult to identify because of the availability of commonly used laboratory tests. A complete metabolic panel usually will identify abnormalities of electrolytes, liver function, or renal function. Thyroid function tests and B_{12} are typically put in this category.

Using the mnemonic DELIRIUMS with an 'S' emphasizes to the clinician that delirium usually has more than one cause. The S also stands for subdural hematoma, which can cause a change in mental status. Although the mortality rate of subdural hematomas among younger people is quite high, the prognosis for older people is quite good as long as the diagnosis is not missed. The other difference between older and younger patients with subdural hematomas is that older patients may develop the subdural hematoma over a period of a few hours or days. Although there is some debate as to whether or not all older patients presenting to a hospital with delirium should have some sort of brain imaging, most would agree that because this is a very reversible problem that is not reversible if the diagnosis is delayed, it should be looked for if there has been a history of head trauma or falls or any suspicion that there was an unwitnessed fall.

One of the other causes of delirium not represented in the mnemonic is pain. Recognition of pain, now identified as the fifth vital sign, is improving,

and pain should be considered a readily treatable cause of delirium, especially when associated with elective surgery.

Prevention and Management Interventions

Interventions in the area of delirium can have any or all of the following goals: (1) prevent the development of delirium, (2) reduce adverse outcomes associated with delirium in those patients for whom delirium is not prevented, and (3) provide health-care professionals with alternatives to physical restraints and pharmacological methods in the management of delirium.

Delirium is a complex issue, and interventions that are successful will involve several components, many of which are not easily measured. These include education about the risk factors and screening for the diagnosis of delirium, a culture change about how not to use what seems logical and protective (for example, physical restraints or pharmacological sedation), and the realization that multicomponent interventions are not simple but can be done. Thus, the most consistent message about successful interventions is to use an interdisciplinary team approach and follow geriatric principles. Although not all interventions have reported successful outcomes, the following are a few interventions that have.

In a prospective study of a multicomponent intervention to prevent the development of delirium in hospitalized older patients, patients at risk for delirium were identified using the following six risk factors for the development of delirium: baseline cognitive impairment, eye or visual problems, altered sleep–wake cycle, dehydration, restricted or decreased mobility, or hearing impairment. The standardized intervention protocols that were used in the study included the following:

- A protocol for sleep (back massage, relaxation music, decreased noise, warm milk or caffeine-free herbal tea)
- Recognition of volume depletion and treating as appropriate
- Use of an amplifier or the patient's own hearing aid
- Use of visual aids (the patient's own glasses, magnifying lens)
- Ambulation as soon as possible
- Frequent reorientation.

Development of delirium was reduced by more than one-third (15% of 426 usual care patients versus 9.9% of 426 intervention group patients; OR 0.60, 95% CI, 0.39–0.92). The total number of days of delirium and the total number of episodes of delirium were also significantly lower in the intervention group, but the severity of delirium and recurrence rates were not significantly different. The interdisciplinary team included a geriatric nurse specialist, two specially trained persons familiar with the standardized intervention protocols, a certified therapeutic recreation specialist, a physical therapy consultant, a geriatrician, and trained volunteers. The low rate of delirium in the control group compared to previous studies reflects the study being done within one hospital. Some control group patients who were on floors with intervention group patients probably received some of the interventions. Although a multicomponent intervention such as this seems labor intensive and costly, cost-effective analyses have been favorable.

In another study, 126 patients 65 years or older who were admitted for surgical repair of hip fracture, a high-risk group for development of delirium, were randomized to geriatric consultation or usual care. The geriatric consultation was proactive, which meant that the consultation began preoperatively (for 61% of the patients) or within 24 h of surgery. A geriatrician made daily visits for the duration of the hospitalization. Recommendations, based on a structured protocol emphasizing geriatric principles as well as postoperative medical care, covered areas such as treatment of severe pain, elimination of unnecessary medications, regulation of bowel/bladder function (including discontinuing bladder catheters by postoperative day 2), adequate nutritional intake and early mobilization. Overall adherence rate by the orthopedics team to the recommendations was 77%.

Development of delirium was reduced by about one-third (50% of the 64 usual care patients versus 32% of the 62 consultation patients; OR 0.64, 95% CI, 0.37–0.98). There was a greater reduction of severe delirium, occurring in 12% of the consultation group and 29% of the usual care group (OR 0.40, 95% CI, 0.18–0.89).

Another type of intervention, called the delirium room (DR), was developed for patients for whom delirium is unpreventable or who already have delirium on admission to the hospital. The DR is a specialized four-bed room that provides 24-h nursing care and observation by at least one nurse in the room and that is completely free of physical restraints. The main components of the DR are the following. The four-bed DR is an integral part of an acute care for the elderly (ACE) unit. As such, the patients in the DR receive the benefits of the geriatric principles for which the ACE unit has been shown to be effective in preventing loss of functional decline. Nursing inservices and nurse-developed protocols on

how to identify and manage delirious patients are necessary. The DR is not isolated from the rest of the floor; rather, it is the closest room to the main nurses' station. Since awareness is one of the components of the comprehensive approach to delirium (discussed previously), having a location on a busy medical floor called the delirium room can raise awareness for health-care professionals that delirium is a serious diagnosis, with serious consequences. Putting delirious or potentially delirious patients in a room together does not increase agitation, as previous literature might suggest.

The report of the DR showed that over a 12-month consecutive time frame, of the 69 patients with a diagnosis of delirium (according to the *International Classification of Disease*, 9th edition) in the DR, negative associations found in other studies of delirious patients (such as loss of function, increased length of stay, and increased mortality) were decreased. Only 13% of the patients lost physical function, and none of the 69 delirious patients died during their stay in the hospital. Mean length of stay for these patients was not significantly different compared to the length of stay for all other patients over the age of 70 during the same time frame. No physical restraints were used, and only 29% of the patients received new orders for medications considered to be pharmacological restraints (haloperidol, risperidone, or lorazepam), all at total daily doses less than 2.0 mg.

One of the risk factors for development of delirium is the hospital environment. But if patients are sick, how can this be prevented? Two novel studies of home hospital care have shown lower rates of delirium among medical patients cared for in the home compared to similar patients cared for in the hospital. In one study, 100 patients with a mean age of 76 years (70% from home, 25% from nursing homes, and 4% from hostels) and with medical illnesses such as acute infections requiring intravenous antibiotics, deep venous thrombosis, minor cerebrovascular accidents, or cardiac failure were randomized within 24 h of diagnosis to either home or hospital. The researchers used the term confusion instead of the formal diagnosis of delirium. They found a lower incidence of confusion (0 versus 20.4%; $P = 0.0005$) in the home group compared to the hospital group.

Another study of older patients admitted to the hospital with pneumonia, congestive heart failure, chronic obstructive pulmonary disease, or cellulitis randomized patients to either home for continued care or usual care to be completed in the hospital (average length of stay 2.9 days versus 4.9 days). The home care group had an adjusted odds ratio for development of delirium of 0.25 (0.11, 0.58, adjusted 95% CI).

Two other interventions worth mentioning in the areas of prevention and management of delirium are exercise and involving family members in the care of the older patient.

Physical Restraints

Restraint-free care should be the standard of care for patients who are at risk for developing delirium or who have already developed delirium. This is based on several reasons. Studies have shown both that physical restraints are an independent risk factor for development of delirium and that use of physical restraints is significantly related to severity of delirium. Furthermore, the proposed reason for the use of physical restraints among delirious patients, to prevent injury, primarily related to falls, is misconceived. Of three studies in long-term care institutions of restraint reduction programs, two showed no change in fall rate and one showed an increase in fall rate. However, all three studies showed a decrease in fall injury rates. Of two studies in the hospital setting, restraint reduction was not associated with an increase in falls. One of the hospital studies reduced restraint use from 52 per 1000 patient-days to just 0.3 per 1000 patient-days. The other hospital study showed good success on the regular wards but only modest success in two of six intensive care units in restraint reduction ($\geq$20% reduction) but reported that no deaths occurred as a result of a fall or disruption in therapy, including intensive care unit patients on mechanical ventilators.

Restraint-free environments have been achieved in some geriatric departments within European hospitals, ACE units within US hospitals, and some nursing facilities.

Pharmacological Restraints

Based on the available data concerning medications used in the management of delirium and the commonly accepted reason to use them (for patients whose behavior interrupts medically necessary care or puts themselves or others at risk of physical harm), antipsychotics should be considered a form of restraint until further evidence shows otherwise. Currently no antipsychotic or other pharmacological agent is approved by the US Federal Drug Administration for the treatment of delirium.

In patients with schizophrenia, antipsychotics can improve behavior and function, with sedation being a common side effect. However, delirium is not analogous to psychosis, and this may be the reason why antipsychotics have not been shown to do the same in patients with delirium. It is argued that they

Table 4 Use of antipsychotics in delirium

1. There is not enough evidence for the routine use of antipsychotic or other pharmacological approaches in the management of delirium.
2. Based on general geriatric principles, non-pharmacological interventions that have no or less risk should be tried before any pharmacological approach is tried.
3. If pharmacological agents are used, the lowest possible dose should be tried first, keeping in mind that the goal is a manageable and awake, not oversedated, patient.
4. Based on very limited data, the category of drug of choice seems to be antipsychotics, not benzodiazepines or sedative hypnotics.

control behavior, but it is unclear whether this is through the sedation effects of the drugs or through their effect on the neurotransmitters thought to play a role in delirium. One of the main problems with antipsychotic drugs, whether atypical or typical, is that they are not pure in their mechanism of action. For example, although risperidone primarily affects serotonergic (5-HT_2A) receptors, it affects to some extent dopaminergic and α-1 receptors. Although olanzapine affects the 5-HT_2A receptors, similar to risperidone, its sedation properties are probably due to its effect on the histaminic receptors. Clozapine also affects histaminic as well as muscarinic receptors, and quetiapine has varying effects on histaminic and α-1 receptors but also has a small effect on dopaminergic and 5-HT receptors.

The available data for use of antipsychotics in the management of delirium are poor because of the populations studied, the types of studies done, or the presence of the common mistake of not including a placebo group in order to measure the natural course (duration) of delirium without pharmacological intervention. For example, one of the often-referenced studies condoning the use of antipsychotic medications compared haloperidol, chlorpromazine, and lorazepam in 30 delirious hospitalized patients with AIDS, whose mean age was 39.2 years (range 23–56 years). Another study comparing haloperidol and mianserin included 60 patients with a mean age of 65 years and did not have a control group either. Thus, although they reported improvement on a delirium rating scale at 1 week, one questions whether or not patients would have improved by this time anyway. It should be noted that one randomized controlled trial of a non-pharmacological intervention to prevent delirium found that even in the control group patients that developed delirium, the average total number of days of delirium was approximately 2.5.

Newer studies with atypical antipsychotics are also wrought with this error of not taking into account the duration of delirium without medication. A prospective study of 64 patients with delirium who received risperidone reported improvement at day 7. Olanzapine was evaluated in a retrospective study of 11 delirious patients compared to 11 other patients who received haloperidol. It took 6.8 days and 7.2 days, respectively, for the peak clinical response.

The proper dosage of antipsychotics has also never been established. One recent recommendation is that if severe agitation is present, haloperidol doses of 0.25–1.0 mg can be used as often as every 20–30 min, with a maximum 24-h dose of 3–5 mg. This dose is recommended because D2-dopaminergic receptors are saturated at low doses, and thus theoretically doses above 5 mg over a 24-h period are likely to increase adverse events without providing additional clinical benefit. The goal should be an awake patient who is manageable, not a sedated patient, and the drug should be tapered and discontinued as soon as possible. One study of delirious ICU patients, mostly surgical with an average age of 65 years, compared haloperidol and olanzapine. For patients over 60 years, haloperidol was initiated at 0.5–1.0 mg and olanzapine at 2.5 mg every 8 h. Younger patients were initiated at doses of 2.5–5.0 mg and 5 mg, respectively. The delirium index (measure of severity) decreased over time, and clinical improvement was the same in both groups. The study did not detail what percentage of patients was mechanically ventilated.

Table 4 includes conclusions based on the available current data.

See also: Dementia.

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Dementia

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Glossary

Dementia – The acquired loss of cognitive abilities in more than one domain.

Introduction

Dementia is the acquired loss of cognitive abilities in more than one domain. It can be progressive or not and reversible or not. The differential diagnosis of dementia includes many conditions such as degenerative and vascular, as well as those associated with movement disorders. Treatment depends upon the kind of dementia but should include both biological and psychosocial approaches.

Dementia, the loss of thinking abilities in more than one intellectual domain, represents a great challenge to individuals and to societies. Not all dementias are progressive, but many are – particularly those that affect the elderly. Dementia is often associated with memory impairment but can present itself in various different forms with quite variable initial symptoms and subsequent courses. Dementias, especially those that progress, can lead to considerable functional disability and dependence on others, as well as eventually contributing to death.

The concept of dementia emerged in the mid-1800s. During this period of medical history, neurology and psychiatry were less differentiated from each other. Confusion reigned as to the causes of and mechanisms for the deterioration in the intellect found in a variety of conditions. What constituted a psychiatric and neurological condition was less clear, although even today mind and brain issues continue to perplex us. The thought disorder in schizophrenia was labeled dementia praecox, although it was not until modern times that the cognitive dysfunction in schizophrenia was fully appreciated. Syphilis was a common cause of dementia (general paresis of the insane) at the turn of the century. In the early 1900s, the field of brain psychiatry emerged, and researchers began to study the brain pathology associated with dementias. Dr. Alois Alzheimer contributed not only to describing the condition that now bears his name, but also to the understanding of vascular dementia, syphilis, and Pick's disease.

In modern times, the concern about dementia has increased because of the growing number of affected people due to a variety of social and environmental issues that characterize modern life. Projections of some of these trends into the future predict that more cases of dementia will burden individuals, their families, and the health-care system in the twenty-first century. Most notable among the social trends is the aging of the world's population. Thus, degenerative and vascular dementias will become more common. As the number of persons with HIV/AIDS increases and current therapies keep people alive longer, more AIDS-related dementias will occur. The likely increase in environmental toxic exposures and infectious diseases caused by industrial pollution and global warming affecting ecosystems will affect larger numbers of people – particularly those grouped in urban areas. Viral and other encephalitides may spread more rapidly, perhaps leading to, for example, another influenza epidemic. More conflicts over resources such as water and oil may lead to an increase in war-related head injuries causing dementia among both military and civilian participants.

Epidemiology

Dementia affects individuals of all ages. By definition, in order to be labeled demented, a person must have had a higher level of intellectual ability prior to a decline. More dementias affect individuals who have been alive long enough to gain intellectual skills and then to lose them. World-wide estimates of the incidence and prevalence of dementia are difficult to obtain because of the difficulty in making the diagnosis and recording cases in the developing world. Moreover, which conditions are included in the category of dementia and what forms of dementia should be included in these surveys vary across the studies. In many texts, it is said that degenerative dementias are the most common causes, with Alzheimer's disease (AD) being the most common in that category. Following AD, conditions such as frontal lobe dementia and dementia of the Lewy body type account for significant percentages (perhaps 10–20% each) of dementia cases. It is also said that vascular dementia is the second most common etiology, particularly in populations at risk for vascular disease, such as African Americans in the United States and some Asian populations. However, it is increasingly recognized that individuals with so-called vascular dementia often suffer from a mixed overlapping pattern with AD. Also, patients with AD often display vascular lesions such as amyloid angiopathy and arteriosclerosis. From a more inclusive viewpoint, however, dementia includes large numbers of individuals who are victims of famines and wars. Individuals whose brains are inadequately nourished or affected by head trauma fit within the definition of dementia and should be included in a full accounting of the dementias. Even in the United States, thousands of young children's brains are damaged by lead; mercury pollution is also a growing threat to neurological health.

Diagnostic Evaluation

As shown in **Table 1**, many different conditions can cause dementia. Such lists of the dementias can range from the 10 most common dementias to huge numbers of rare conditions of various degenerative, metabolic, and infectious disease types. Some dementias that are caused by ongoing irreversible processes in the brain are progressive. Others, such as head injury, are relatively fixed in their course. Although some dementias are irreversible because the underlying pathology cannot be interrupted, they should not be considered untreatable. All dementias are treatable

Table 1 Broad causes of dementia

Type	*Examples*
Degenerative	Alzheimer's disease, Parkinson's disease, Huntington's disease, frontal lobe dementia
Vascular	Multi-infarct, hematomia, white matter pathology
Infectious	Slow virus, chronic meningitis
Metabolic	Thyroid distinction, alcohol related
Head trauma	Missile wounds, closed head injury
Psychiatric	Depression, chronic schizophrenia
Genetic	Storage diseases

with psychosocial interventions, and many can be ameliorated by biological therapies. This article discusses the dementias in two broad categories: reversible and irreversible. It must be recognized, however, that these terms are relative and that even so-called reversible dementias due to metabolic causes may not allow an individual to return fully to their baseline intellectual state. There is tremendous overlap between the different kinds of degenerative dementias and between degenerative dementias and vascular disease. Particularly in the elderly, multiple conditions may affect an individual's brain function contributing to dementia.

Thus, applying the label dementia necessitates that the physician try to determine a more specific cause. The first step is to determine that dementia is the most appropriate label. For children who have never been intellectually normal or who have not deteriorated from a previous baseline, a more appropriate label may be amentia or mental retardation. Children and adults may have an acute metabolic disturbance such as abnormal electrolytes or exposure to toxins such as alcohol. Such deliriums may be fully reversible by treating the underlying metabolic problems. However, delirium can also coexist in persons with dementia.

It is often quite difficult to differentiate psychological or psychiatric causes of cognitive impairment. For example, depression – particularly in the elderly – can manifest as a cognitive retardation and create a picture of dementia. Some have labeled this as a pseudo dementia, but its cognitive impairment is genuine and is best labeled as an actual form of dementia. Once again, these psychiatric causes overlap with neurological forms; thus, patients with AD and Parkinson's disease can be demented from both the underlying neurological condition and depression.

The nosological problems of dementia can be illustrated by the concepts of cortical and subcortical dementia. These terms are falling out of favor but represent an attempt to categorize degenerative and other dementias depending on the alleged primary location of the pathology causing the cognitive impairment. Prototypical so-called cortical dementias include AD and frontal lobe dementias. Prototypical so-called subcortical dementias include progressive supranuclear palsy and Huntington's disease (HD). Although these terms were somewhat heuristic in identifying that there was heterogeneity in the dementias, the pseudo-anatomical nature of the terms is apparent, as subcortical pathologies exist in AD and cortical pathologies in HD, for example.

Moreover, the associated clinical symptoms (for example, motor disturbances) are often the obvious difference between the two categories. The use of the terms cortical and subcortical is falling out of favor even for didactic or educational purposes, which should be based on our best scientific understanding. Certainly much cortical pathology occurs in AD, and the basal ganglia appears to be more of a target in HD. Determining the relative importance of different systems underlying cognitive symptoms and their treatment is difficult. The first drugs approved for AD were based on ameliorating subcortical pathology in the cholinergic basal forebrain.

The clinician should take a careful history to determine the nature and course of the dementia. General physical, neurological, and psychiatric examinations should be given to search for signs of associated illness that might give clues to the cause of the dementia. A mental status exam that covers the domains of attention, executive function, language, praxis, and perception and that considers different types of short- and long-term memory should be conducted. If the degree of cognitive impairment is mild, neuropsychological assessment to establish the presence of cognitive impairment greater than expected for age and education and to determine the patterns of cognitive impairment should be considered. Moreover, in questionable cases of dementia, such a sensitive, detailed assessment can serve as a baseline for subsequent evaluations. For many of the dementias, the boundaries between normal and abnormal or pathological are fuzzy. The concept of mild cognitive impairment has been invented to try to characterize preclinical forms of dementia. However, the term has proven to be quite controversial and should not be used clinically. Some argue that patients prefer the term mild cognitive impairment rather than brain aging; others disagree with early dementia. Any progressive dementia has a phase in which cognitive impairment is present but the clinician does not believe that the functional impairment is sufficient to warrant the label of dementia. Mild cognitive impairment is based on arbitrary thresholds on various cognitive and functional criteria, is inconsistently used by experts, is very heterogeneous, and often does not predict subsequent course.

Once the presence of dementia has been established on the basis of history and the physical examination, it is often important to conduct additional laboratory tests to pinpoint the specific cause. Brain imaging such as computerized tomography (CT) or magnetic resonance imaging (MRI) can determine whether there are any structural lesions that cause dementia, such as strokes or tumors. The use of single photon emission computerized tomography (SPECT) and positron emission tomography (PET) scans (i.e., functional imaging) in the evaluation

of dementia is controversial. Specific patterns of a reduction in blood flow or glucose utilization can be associated with AD (parietal temporal) and frontal lobe dementia (frontal and/or temporal), but the overlaps are considerable. The diagnosis should be made based on the clinical pattern of impairment and not on the imaging. An electroencephalogram (EEG) may be used in rare cases where the cognitive impairment appears to fluctuate in a manner consistent with seizures. Moreover, in some conditions it may provide diagnostic assistance. For example, in Pick's and frontal lobe dementias, the EEG may appear normal later in the course than in AD. In a rare infectious course of dementia called Creuzfeldt–Jacob disease, characteristic sharp wave activity may make the diagnosis more certain. Blood tests should be conducted to make sure that there are no metabolic causes of the dementia, focusing particularly on thyroid and vitamin B_{12}. Finally, in rare circumstances it may be worthwhile to consider a spinal tap to examine cerebrospinal fluid. If suspicion of some inflammatory, vasculitus, or infectious process exists, then examination of fluid may aid the diagnosis. Research studies show lower cerebrospinal fluid (CSF) levels of amyloid and higher levels of tau in AD, but the overlap with normal and other neurological disease controls is considerable. No clinical diagnostic consensus statements recommend their use in routine practice. Finally, in rare cases a brain biopsy may be helpful, particularly in younger people if evidence of vasculitis or a specific metabolic or degenerative process is present. However, it is often difficult to make the diagnosis based on the limited tissue often obtained at biopsy. Moreover, the critical issue to consider is whether the brain biopsy would affect treatment.

Types of Dementia

As mentioned previously, the dementias are discussed in two broad categories, reversible and irreversible, recognizing that there is overlap in these categories and that individual patients often suffer from several different processes manifesting at the same time.

Reversible Dementias

The principal reversible dementias are metabolic. Hypothyroidism and exposure to industrial or environmental toxins should be considered; iatrogenic cognitive impairment due to medications is a common example. Depending on the acuteness and intensity of the metabolic disturbance, the clinical presentation may be more similar to delirium than dementia. These dementias are reversible, but often not completely, depending on the length of exposure of the brain to the abnormal metabolic environment.

Perhaps the most challenging reversible dementia is depression, because it often coexists with a neurological disease. In some circumstances it can be the initial symptom of a condition such as AD. The clinical adages that "people with AD do not complain about their memory problems; their families do" and "the patient with depression actually is the one who complains" are worth considering. All patients with dementia are at risk for depression because of their reaction to the underlying illness. Moreover, patients with vascular dementia and Parkinson's disease may be more at risk because of lesions in areas of the brain that affect emotions. Counseling should be offered to all patients with depression, and a therapeutic trial of antidepressive medications may assist the patient and aid in the differential diagnosis as well.

Normal-pressure hydrocephalus, another rare dementia, is associated with early onset of gait ataxia and incontinence. Abnormal cerebral fluid pressure dynamics can be treated by placing a ventricular shunt and draining fluid from the brain. The principal problem is predicting who will benefit from a shunt. Brain imaging often shows enlarged ventricles out of proportion to the degree of atrophy but is often specific for the diagnosis. Often the removal of a small amount of CSF to see if there are any changes in the patient's gait is the best predictor of whether there will be benefit from the shunt, which carries the risk of infection and bleeding.

Irreversible Dementias

Unfortunately, many dementias are partially or completely biologically irreversible. However, as mentioned previously, it is important to recognize that all dementias are treatable. Some of these irreversible dementias are preventable. For example, automobile accidents in civilian populations and projectile wounds in military populations are common causes of brain damage that cause dementia. Some improvements can occur in these conditions for a period of time after the initial insult, but affected individuals are left with varying degrees of impairment and often severe limitations in function.

Vascular dementias are another large category of irreversible but potentially preventable dementias. The classification of the vascular dementias is complex and has evolved over the last several decades. Multiple small infarcts, hematomas of various kinds, single strategic infarcts, vasculitis, and other disturbances in vascular mechanisms can all cause dementia. They can be differentiated from the

degenerative diseases, although overlapping syndromes are common. Neuroimaging may show strokes, white matter ischemic changes, or other vascular lesions. The onset may be abrupt and the course more stepwise in its progression. Vascular dementia is largely treated by modifying risk factors. Some drugs approved for the treatment of AD may also help patients with vascular dementia, such as the cholinesterase inhibitors and memantine, although these are off-label treatments.

The most common degenerative dementias are AD, frontal lobe dementia, and those associated with Parkinsonism. There is considerable overlap between these different conditions, even in families in which known genetic mutations cause degenerative dementia. Family members with the same mutation can demonstrate different pathologies and clinical course. Motor symptoms, either impoverishment or overactivity, are useful in differential diagnosis. Parkinsonism is characterized by bradykinesia or slow movement, rigidity, and tremor and can be seen in a variety of conditions, including classic idiopathic Parkinson's disease as well as other, rarer neurodegenerative conditions. Dementia of the Lewy body type is characterized pathologically by the Lewy body (found in Parkinson's disease in the mid-brain but in this disease throughout the cortex as well) and clinically by Parkinsonism fluctuating attention and hallucinations. HD is associated with abnormal involuntary movements, such as chorea, and is the prototypical autosomal dominant cause of dementia. AD is usually characterized by initial presentation with memory difficulties followed by other cognitive impairments in the domains of language, perception, and praxis. Frontal lobe dementia is associated with early disturbances in attention and executive dysfunctions such as goal setting, planning, and monitoring one's own behavior. In addition, frontal lobe dementia is often accompanied by disturbances in behavior and emotion. However, the clinical overlap between AD and frontal lobe dementia is considerable.

Treatment

The treatment of any person of any age with any degree of cognitive impairment must be individualized. Clearly, if there are underlying causes and risk factors for deterioration, they must be addressed. It is always important in the treatment of dementia to have clear therapeutic goals established in partnership with the patient and family. Often, the concept of quality of life is an important guide to therapy, as this reflects the values of the individual and his or her family. This section discusses both non-pharmacological and pharmacological treatments of dementia. Remember that non-pharmacological approaches are always appropriate. Pharmacological treatment may be useful in some circumstances but may also contribute to patient dysfunction because of side effects.

Non-pharmacological Approaches

Non-pharmacological approaches include providing educational material, suggesting counseling, and recommending environmental modifications in the patient's home or other residential care environment. A considerable degree of misunderstanding, even in experts, exists with regard to the labels that are used to classify dementia. Hence, informing patients honestly about the uncertainties of diagnosis and prognosis is important. It is helpful to provide patients and families with some sense of the stages that the patient may go through, even though the course of illness can be quite variable. A diagnosis of dementia can be stressful for both the patient and the family. Support groups offered by lay organizations such as Alzheimer and Parkinson's associations are quite helpful to both patients and caregivers in learning practical management skills and sharing means of adaptation. Wherever the patient lives, the environment can be examined for modifications that may improve quality of life, for example, to provide adequate privacy, social interaction, and exercise. The use of household appliances should be monitored. A major safety issue is driving. Patients should be evaluated and counseled to stop driving when appropriate. A wealth of literature is available about modifying environments to prevent wandering and other risks to patients.

Biological or Pharmacological Treatment

As mentioned previously, if a dementia is essentially reversible or has a potentially reversible component, it is important to treat the underlying cause. Many medications can contribute to cognitive impairment, particularly prescribed and over-the-counter medications with anticholinergic and antihistamine side effects. A few drugs have been approved for the treatment of mild to moderate AD, such as cholinesterase inhibitors (donepezil, galantamine, and rivastigmine). Many other dementias have a cholinergic component, including Parkinson's disease and dementia of the Lewy body type and probably vascular dementia. Cholinesterase (ChE) inhibitors might be tried in these conditions even though they are off-label. Moreover, there is evidence that some

patients with vascular dementia respond to this class of agents.

Memantine acts through a different neurotransmitter, glutamate, as a glutamate receptor antagonist. This medication has been approved for moderate to severe stages of AD but can be considered off-label for other degenerative dementias and vascular dementias as well.

Medications can also be used to treat the noncognitive or behavioral symptoms of dementia. Depression, agitation, hallucination, delusions, social inappropriateness, and apathy can disturb patients and caregivers more than the behavioral symptoms. Some evidence suggests that medicines used for treating this phenomenology in psychiatric diseases can be used in patients with dementia. Antidepressants are used for demented patients with depression. Novel neuroleptics are the most widely used drugs for agitation and psychosis, but they have significant risk of side effects.

The holy grail of drug development in dementia is to find medications that actually prevent or modify the biological course of the disease. A variety of approaches, such as estrogen replacement therapy, anti-inflammatory agents, antioxidants such as vitamin E, and statins, have been assessed. Epidemiological and basic science studies suggest such candidates for slowing the biological progression of AD. Since there are overlaps in the pathogenetic mechanisms of AD and other conditions such as vascular dementia, these classes of potential disease-modifying agents may have effects in several dementias. However, no adequately sized and conducted studies have demonstrated any disease-modifying action from any drug. No drugs are approved as agents to modify the progression of a dementia save those that modify risk factors.

So-called complementary and alternative medicine approaches are also often used by patients to prevent cognitive deterioration. However, no such products have been demonstrated in adequate trials to modify the progression of any dementia. Gingko biloba is widely used and is currently being studied but cannot be recommended.

Future Directions

Dementia represents both a tremendous challenge and opportunity to apply powerful new scientific approaches to understanding pathological mechanisms and developing more effective therapies. However, we must be careful about exaggerating the likelihood that progressive dementias will yield quickly to our technologies. The boundary between some degenerative conditions and aging mechanisms is not clear, and thus attempts to slow the biology of these age-related degenerative conditions may be tantamount to finding a neurological fountain of youth. Currently, genetic and molecular biological approaches are exciting and offer hope. But excessive hype leads to the possibility of creating false hope. Moreover, focusing on genetic factors in late life may result in ignoring effective preventative therapies at young ages, such as preventing exposure to toxins. It is remarkable that the consequences of lead poisoning on the brains of young children (i.e., dementia and other forms of cognitive impairment) have been known for centuries but were not adequately acted upon. Even in a wealthy country like the United States, children are still exposed to dangerous levels of lead. Moreover, as we continue to pollute our environment with a variety of manmade chemicals, it is quite possible that environmental causes of dementia will become more common in adults. Thus, the major contributors to the increase in incidence of dementia include the aging of the population and the social and environmental stressors that will contribute to poor cognitive health.

Ethical issues about social justice and priorities for our health-care system will continue to be important. We seem excessively enamored with the power of genomics to create more effective medications. The medical profession has been criticized for its close alliance with the pharmaceutical industry. So, too, the bioethics establishment is said to be coopted by medicine. Safety issues with new medications and studies that show little improvements in efficacy associated with greater costs challenge the viability of current drug development approaches. Many ethical issues remain in research on developing more effective drugs for dementia. For example, most countries have not adequately dealt with the issue of informed consent (i.e., how to use proxies to provide informed consent in patients with no or reduced capacity to do so themselves). Now that the drugs are available on the market, when is it appropriate to use placebos in drug trials? Finally, what are the appropriate goals for treatment, especially in severe dementia? What evidence is there that the drugs have benefit on quality of life or health-care costs?

It has been a century since many of the causes of dementia were first identified by brain psychiatrists such as Alois Alzheimer. Perhaps it is time to reflect on what we have learned about these conditions so that the next 100 years can be guided by greater wisdom than we are currently demonstrating.

See also: Dementia: Alzheimer's; Depression; Parkinson's Disease.

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Dementia: Alzheimer's

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Glossary

Alzheimer's Disease – A degenerative brain disease characterized pathologically by cell loss associated with neurofibrillary tangles and plaques.

Delirium – Acute confusional state.

Introduction

Alzheimer's disease is considered a degenerative brain disease and was first described in 1906. As the world's population ages, it will become more common. It is characterized pathologically by cell loss associated with neurofibrillary tangles and plaques. The etiologies are unknown, but genetic factors play a role in the condition. The diagnosis is primarily one of exclusion, and the treatment a combination of pharmacological and non-pharmacological approaches. Future research challenges and ethical issues are considerable.

Alzheimer's disease (AD) is an eponym that has been with us for almost 100 years. Although a single label, it includes a variety of different clinical pictures and biologies. It is most often considered a degenerative brain disease characterized by senile or neuritic plaques and neurofibrillary tangles. In 1906, Dr. Alois Alzheimer described the first case of what became called Alzheimer's disease in a woman who presented progressive cognitive and behavioral impairment at the age of 51. Clinically, AD often presents with memory problems, but subsequently progresses to involve other cognitive abilities and behavioral symptoms such as agitation and even frank psychosis.

Since its original description and naming as a disease by Emil Kraeplin in his psychiatry textbook in 1910, we have come to know much about AD. However, as time has passed the picture has become more complex, not less. As with all degenerative diseases, AD is characterized by a progressive loss of neurons in the nervous system in association with a variety of pathological features. However, it remains controversial as to what are the respective roles of neurofibrillary tangles and senile plaques in contributing to neuronal death. Variable numbers of plaques and tangles are found in individuals with AD. Moreover, a variety of genetic lesions can cause early-onset AD and modify late-onset disease. Thus, heterogeneity of the biological substrate of AD is the watchword.

One of the great historical and current controversies, recognized even by Alzheimer himself, was so-called presenile dementia and whether this condition occurring in younger people was fundamentally

different than senile dementia occurring in older persons. The relationships between the normal processes of brain aging and AD also remain perplexing and controversial.

The term mild cognitive impairment has joined a long list of labels that have been applied to individuals who have cognitive impairment but not of a magnitude sufficient to warrant the label of dementia. Previous terms include benign senile forgetfulness, aging-associated memory impairment, and aging-related cognitive decline. Logically, any degenerative condition such as AD must have a preclinical phase that is characterized by cognitive impairment unassociated with functional decline sufficient to warrant the label dementia. The term mild cognitive impairment is used inconsistently by experts, is based on arbitrary thresholds in impairment, and has heterogeneous features and outcomes. Some patients prefer a label such as mild cognitive impairment to brain aging or early dementia, but because of the controversy it should not currently be used clinically.

AD is said to be the most common dementia worldwide. Alzheimer's Disease International claims that there are perhaps 25 million people with AD around the world. The veracity of this figure is uncertain because of different epidemiological approaches used in different countries. In addition, the arbitrary distinctions among normal brain aging, mild cognitive impairment, and AD produce different results in different studies depending on the criteria used. Nevertheless, it is clear that as the population of the world ages, the number of individuals with degenerative diseases such as AD will increase. However, other forms of dementia associated with social and environmental disturbances, such as war, epidemics, and environmental toxins, will also likely increase in frequency.

Pathology

As with most degenerative dementias, AD is associated with neuronal loss in association with specific pathological features. Widespread pathology in the cortex contributes to atrophy visible at autopsy and clinically on neuroimaging. This cell loss is accompanied by extracellular neuritic plaques and intracellular tangles as described by Alois Alzheimer, but a variety of other changes are also apparent, such as changes in blood vessels, granulovascular degeneration, and Lewy bodies. The senile or neuritic plaque is an accumulation of abnormal proteins, including amyloid, surrounded by abnormal neuritic processes. The neurofibrillary tangle is found inside certain neurons and is composed of tau in a paired helical configuration associated with other proteins. Although AD affects many populations of neurons, it is selective in impairing some more than others, although the pattern is quite variable in different cases. Hippocampal involvement is universal and underlies some of the memory disturbance. In addition to the cortical pathology, changes occur in subcortical structures such as the nucleus basalis of Meynert (cholinergic basal forebrain), noradrenergic locus ceruleus, and serotonergic raphe nucleii. It is said that a definite diagnosis of AD can be made only on the basis of autopsy findings. However, even at autopsy it is sometimes difficult to differentiate normal aging from AD; different neuropathological criteria emphasize different features. The distinction from normal is more quantitative than qualitative. Moreover, many elderly individuals suffer from mixed dementia, that is, a combination of AD changes with vascular and/or Parkinson's features.

Etiology

Shortly after its original description, it became known that AD can be familial. Rarely, the pattern is one of autosomal dominance in which 50% of children on average inherit the gene from an affected parent. The fact that individuals with Down's syndrome or trisomy 21 are more at risk for developing plaques and tangles later in life provided motivation to examine this chromosome in AD. A number of mutations have been described in the amyloid precursor protein, the gene for which is located on chromosome 21, causes dementia in some rare families. These mutations alter the procession of the large (approximately 700 amino acids) precursors, which in turn allows the accumulation of the smaller (approximately 42 amino acids) amyloid protein itself. Secretase enzymes clip the precursor into smaller proteins as a part of normal processing, but mutations affect these shortening activities.

Other mutations have been described on chromosomes 1 and 14 in genes coding for proteins called presenilins (which may be related to the secretases), which are also involved in disrupting amyloid processing. Although these autosomal dominant forms are rare ($<$1–2% of cases), other genes modify the risk for later sporadic forms. The only well-established susceptibility locus is apolipoprotein E (ApoE) located on chromosome 19. ApoE is a cholesterol transport protein and exists normally in several forms. Individuals who have one or particularly two copies of the ApoE4 form of the protein are at higher risk for AD. Other susceptibility genes probably exist but remain to be clearly demonstrated.

A variety of other theories as to what causes AD have developed. Antioxidant theories of AD are similar to those used to explain normal aging. The accumulation of free radicals in the brain is said to damage nerve cells. Of late, inflammatory hypotheses have achieved some prominence, as atypical cellular and chemical inflammatory features are associated with senile plaques. Other studies have implicated the mechanism of excitatory cell death in AD. According to this theory, neurons die through excess stimulation by excitatory amino acid neurotransmitters such as glutamate. Finally, many parallels have been drawn between the potential etiology mechanisms in AD and vascular dementia, focusing on pathology in blood vessels. Amyloid can accumulate in vessel walls. Moreover, alterations in cholesterol metabolism have been claimed to be involved in both conditions.

The major risk factor for AD is advancing age. However, the relationship between normal age-related processes in the brain and AD remains controversial. To date, there is no way to make a diagnosis of AD with certainty in either life or death that does not involve the establishment of some arbitrary threshold in a clinical or biological feature present in both AD and aging but that is more apparent or severe in those with dementia. Cerebrospinal fluid (CSF) markers for tau (elevated) and amyloid (reduced) are affected in AD, but the values overlap with normal aging and other neurological diseases. Hence, well-accepted clinical consensus panels have not recommended their routine use. Combining multiple markers may lead to more definitive diagnostic tests, but they have not done so to date. The often-made statement that AD is not normal aging is more a political than a scientific one. Is AD a form of severe brain aging?

Diagnosis

AD is characterized by the insidious onset and slow progression of intellectual difficulties, usually starting with memory impairment. It can begin with language, praxis, perceptual, or executive dysfunction. The illness is said to evolve through stages from mild to moderate to severe. In late stages, cognitive difficulties are often associated with behavioral disturbances. In the mild stages, patients are often independent and suffer only from memory problems and perhaps some mild attention difficulties. In the moderate stages, they become dependent on others for assistance with instrumental (more complex) activities of daily living, and a broader pattern of intellectual impairment develops. In the severe stages, dependence is even greater and the patients may lose the ability to perform even basic activities of daily living, including personal hygiene. In profound stages, patients may be mute and completely dependent on others for care. AD is said to be a terminal disease; life expectancy is reduced, although death usually occurs through infection, secondary to immobility (pneumonia, for example).

Although these features are typical of AD, they are not specifically exclusive to AD. AD is often considered a diagnosis of exclusion, meaning that the diagnostic assessment discloses no other explanation for the cognitive impairment. However, depression and normal aging are also not accompanied by any alterations in biological tests to allow clear differentiation from AD. Thus, the clinician is often left with a diagnostic dilemma in mild cases as to whether a person has normal age-related cognitive changes, depression, or AD. Depression can also co-exist with a neurological cause of dementia. Delirium (acute confusional state) is also commonly associated with AD. An abrupt change in mental status in AD should prompt a search for a metabolic or infectious cause of the decline. No biological test has been approved to diagnose AD, although hundreds of claims for the utility of various approaches have been made.

Treatment

The treatment of any dementia involves both biological and psychosocial interventions, or, to put it another way, drugs and non-pharmacological approaches. All dementias demand attention to the therapeutic goals of patients and families and to the resources of the family and community to provide such services. These interventions should be tailored to individual preferences as well as to the different stages of the disease. Maintaining or even enhancing quality of life of the patient and caregivers should be an overarching goal.

Drugs for Improving Cognitive Symptoms

Five drugs have been approved for the treatment of cognitive symptoms in AD. Four of them are cholinesterase inhibitors that act on the deficiency in the neurotransmitter acetylcholine associated with the loss of cells in the cholinergic basal forebrain. The first approved was tacrine, but this drug is not used today because it needs to be administered four times a day and causes reversible liver toxicity. Donepezil, the most commonly used drug, can be administered once a day and is not associated with liver toxicity. It shares with all the cholinesterase inhibitors the tendency to cause some degree of gastrointestinal upset such as nausea, vomiting, diarrhea, and/or

abdominal cramps. Moreover, muscle cramps and sleep disturbances can also occur. The latest cholinesterase inhibitor approved, galantamine, now can be given once a day. Rivastigmine is not as widely used as the other two because it causes more severe gastrointestinal side effects and is required to display a black box FDA warning concerning weight loss. All of the cholinesterase inhibitors have a similar efficacy profile, and decisions about which to use have more to do with side effects (claims that they have other properties that may be advantageous and differentiate them from each other are of unclear clinical relevance). The cognitive benefit of these drugs is very modest and the impact on activities of daily living rather minimal. Their effects are rarely of sufficient magnitude to improve or even maintain quality of life, although little data exist to support or challenge this assertion.

The last drug approved for the treatment of cognitive impairment in AD is memantine, which acts through a different mechanism, glutamate receptor antagonism. Its efficacy is comparable to the cholinesterase inhibitors, but its side effect profile is different. It occasionally causes constipation, dizziness, and rarely confusion. This drug is also thought to possibly have an effect on any excitatory amino acid overactivity that may occur in AD. However, this mechanism is speculative, and no drug has been approved by the US Food and Drug Administration as a disease-modifying agent. Similarly, the pharmacoeconomic benefits of these drugs (i.e., whether they save health-care dollars by, for example, delaying nursing home placement) have yet to be adequately demonstrated.

Drugs for Modifying the Course of Disease

As mentioned previously, the manufacturers of cholinesterase inhibitors and memantine have claimed that they may have mechanisms of action that may modify the biology of the disease, but these claims have not been demonstrated in clinical studies. As mentioned in the section on etiology, a variety of mechanisms of neuronal damage have been proposed in AD. Associated with each of these theories are potential drug approaches, such as the use of antioxidants, anti-inflammatory agents, or estrogen replacement therapy. Although case control epidemiological studies have supported the idea that the use of these medications may protect from AD, randomized control studies have not supported these claims. Vitamin E (an antioxidant) was widely recommended in the United States for AD, but recent studies questioning its efficacy and raising concerns about safety are curtailing its use. A variety of complementary and alternative medicine approaches have also been suggested to either treat or to prevent the progression of the disease. However, none of these claims has been adequately justified. Ginkgo biloba is widely used around the world, and studies are under way to determine whether it has benefit in memory-impaired patients.

Drugs for Behavioral Symptoms

Patients with AD, particularly later in the illness, develop depression, agitation, and frank psychosis. Though the evidence is not strong, clinicians often use drugs that have been approved for other psychiatric conditions to treat these symptoms. Hence, the antidepressants and the antipsychotics are commonly used. New-generation agents in both classes may have advantages in terms of causing fewer side effects than the tricyclic antidepressants and typical neuroleptics. However, there are dangers associated with the use of all psychiatric drugs in patients with dementia, and non-pharmacological approaches should be emphasized. Avoiding situations that provoke the behavioral symptoms, trying to understand the situation from the patient's perspective, and redirecting attention away from the provocative situation are helpful approaches.

The Future of AD

The most critical issue facing our efforts to better understand what we now call AD is the relationship between AD and normal aging. AD is a heterogeneous class of diseases that is currently subsumed under one single eponym. Numerous genes can cause AD, and many likely await discovery. Neuroimaging studies as well as studies of clinical phenomenology suggest considerable overlap between AD and disorders such as Parkinson's disease, vascular dementia, and frontal lobe dementia. Thus, it is likely that a variety of biological processes affect the brains of older people, and we have only a very rudimentary understanding of how those processes could best be classified diagnostically.

Much effort is being applied to finding a specific diagnostic test, particularly using neuroimaging. Compounds to image amyloid in the brain using functional neuroimaging such as positron emission tomography (PET) are the most interesting. However, they face the same challenge of all biological markers – amyloid is found in varying degrees in most people as they age. AD will likely remain a sociomarker (a label applied clinically). Tremendous energy is being applied to the development of more effective drugs. Most of this attention is focused on

agents that may be able to modify the biological progression of the disease. Most effort has been placed on the hypothesis that agents that would eliminate or remove amyloid from the brain can be developed. Excessive expectations have been raised by approaches such as the use of vaccines or stem cells. The development of effective therapies to reverse or arrest the biologies of AD remains a distant prospect.

In the immediate future, however, there are significant issues with regard to health-care costs associated with AD. As mentioned, pharmacoeconomic studies do not demonstrate convincingly that current drugs provide a significant impact on quality of life and health-care costs. The costs of long-term care are increasing as the population of most countries ages.

Thus, there needs to be considerable energy applied to the development of better psychosocial and educational approaches for patients with AD and their families. Again, recognizing that AD may be a form of brain aging, all of these approaches are relevant to older individuals with memory problems of any cause. Although we focus extensively on the power of biotechnology, we should recognize that information technology allows the opportunity to assist people with memory problems. Computers better educate us, offer opportunities to integrate our lives, and can help us adapt to changes in our cognitive abilities as we age. They could also allow us to monitor and improve the quality of life for people with AD. Regardless of the diagnostic label, older individuals should remain engaged in the community. The advice to continue to keep mentally and physically active should be given to all patients. New opportunities should be created that are adapted to people with memory problems. In Cleveland, for example, the Intergenerational School offers learning opportunities for patients with so-called mild cognitive impairment and AD. This provides not only the opportunity to keep mentally active by reading and interacting with children, but by doing so, it also creates a sense of engagement in community and purpose in life.

For those individuals that eventually become dependent on others for basic activities of daily living, change in residence from home to long-term care facilities will often be required. There are ongoing rapid changes in the provision of residential care for people with dementia. Assisted living programs have been developed for people with milder symptoms. Once the symptoms are apparent, so-called special care units have been developed within the context of nursing homes. However, there are many cultural changes necessary in the long-term care industry. For example, the Eden Alternative emphasizes a resident-focused care that is more harmonious with the natural environment. In long-term care, relabeling AD special care units as memory support units is one example of how to de-emphasize the labeling process and focus on providing functional support. Timeslips is a narrative therapy intervention that encourages creative storytelling even in people with moderate and severe dementia, emphasizing the importance of keeping cognitively vital regardless of diagnosis.

End-of-life care for people with dementia also needs considerable improvement. In general, palliative care is being introduced too slowly into medicine, even for those with more classic terminal illnesses such as cancer. However, many hospices are now developing programs specifically for patients dying with cognitive impairment. Empirical studies suggest that some of the interventions we use, such as feeding tubes and antibiotics, actually do not improve either quantity or quality of life. The critical issue for the future will be how much effort we can apply to feeding individuals with severe dementia. These questions will grow as the numbers of affected people increase and resources for long-term care of older demented people become fewer as other health-care priorities emerge, such as care of children.

Finally, the ethical issues raised by the challenges of dementia will continue to increase. These issues range from prediagnostic assessment of genetic risk to the end-of-life issues just discussed. The future world of medicine is said by some to depend upon molecular biology and genetics. Yet, it is unclear whether individuals at risk for AD can use the complex genetic information that we are now able to provide them. As mentioned, the diagnostic confusion about mild cognitive impairment and AD challenges us to think more deeply about diagnostic disclosure. What are we saying to people when we apply the label AD with all its complexities and heterogeneity?

In the research environment, many ethical issues challenge us, such as finding the appropriate means for gaining informed consent from someone who has lost the capacity to understand a research protocol. Now that we have a few, albeit rather modestly effective, agents, under what circumstances is it appropriate to use placebos in controlled studies?

Finally, there are major ethical issues concerning the relationship between the pharmaceutical industry and the medical profession pertaining to conflict of interest. We must encourage more open reporting of clinical trial results and limit the financial relationships between physicians and industry.

Unfortunately, the field of bioethics has not adequately risen to the challenge of providing society input about these difficult decisions. There is little challenge from bioethicists to the dominance of

genetic rather than environmental medicine and public health. Moreover, bioethicists themselves are facing issues of conflict of interest through their own involvement with pharmaceutical companies. Bioethics tends to support the goals of medicine and physicians rather than challenge them and guide patients and society as a whole.

Conclusion

AD is an important bellwether for the future of medicine and, in fact, the health of our planet. Chronic diseases are proving to be a major challenge to our simplistic biological models of disease. Medicine has not adequately dealt with the boundaries between enhancing normal function and the concept of disease. Finally, the dominance of medical models of care using drugs has replaced broader concerns about the impact of diseases such as AD on individuals and populations. Considering these complex issues in AD may lead to improvements in our values and processes in health care more generally.

See also: Dementia; Genetics; Parkinson's Disease.

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Demography

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Glossary

Demographic Transition – The historical process of change in national populations from high levels to low levels of fertility and mortality.

Demography of the Aged – Examination of the changing social, behavioral, economic, demographic, health, and epidemiologic status of older persons, the factors responsible for these changes, and their consequences.

Demography of Population Aging – Examination of the causes, mechanisms, and societal consequences of age structural changes in the total population.

Population Aging – Changes in the age structure of a population that can be measured by increases in the proportion of total population at older ages and increasing mean or median age of the population. Sometimes also used to reflect the increasing numbers of older persons and high annual rates of growth.

Stable Population – A virtually unchanging population age structure that would result inevitably from the application of given constant schedules of age-specific fertility and mortality.

Introduction

There is growing interest in demographic research directed to various aspects of the field of aging. The term demography of aging has come increasingly to be used to identify studies that adopt demographic perspectives to study aging processes and the

changing characteristics of older populations. In general, demographers focus on the examination of the size, composition, and spatial distribution of populations and the four main determinants of changes in these population characteristics namely, fertility, mortality, migration, and changes in status. In addition, demographers are concerned with the measurement, modeling, and policy implications of past, current, and projected levels and age patterns of these determinants. Age, therefore, is a central focus of attention for demographers and provides a natural rationale for examining many gerontological issues.

Demography as a field is noted for several distinctive features. Demographers address societal issues of major policy importance, such as rapid population growth associated with high fertility, the effects of large-scale population movements, and more recently changes in population structures marked by global population aging. The conceptual models that they bring to bear include not only the interrelationships among the main demographic factors, but also the social, economic, and behavioral determinants and the consequences of major population trends. This broad perspective involves the description and analysis of major population shifts, with the main goal being to measure and untangle the forces that brought them about historically and how they may shape the future. This entails the construction and specification of mathematical and statistical models – life table approaches, stable population models, hazard models, and structural equation models – to provide an understanding of causal relationships, a necessary condition for forecasting future trends. It is acknowledged that demographers have made important contributions in designing and improving the accuracy of major data-collection efforts, such as censuses, vital registration systems, and broad-based population surveys. In recent years, longitudinal surveys have been undertaken increasingly to provide a means for examining important transitions and behavioral changes that affect individuals and their families over the life course. Thus, demography has developed into an interdisciplinary scientific field with distinctive methodological approaches for the empirical study of comparative population structures and changes over time.

The demography of aging actually comprises two distinct subfields: the demography of population aging and the demography of the aged. Each of these subfields has a distinct substantive and methodological orientation. The demography of population aging is primarily concerned with the causes, mechanisms, and societal consequences of age structural changes in the total population, whereas the demography of the aged is concerned with the evolving social, economic, demographic, health, and epidemiological status of older persons who exceed some arbitrarily defined age, most frequently ages 60 and 65. Like the major field of demography, the subfields are interdisciplinary in nature, which has precipitated several new areas of concentrated research interest. Two of these, family demography and biodemography, are examined in a later section.

Demography of Population Aging

Historical Development

The emergence of concern with population aging initially arose from two distinct developments. First, the recognition in the late nineteenth century that an impressive shift in the age structure was occurring in certain national populations and, second, the subsequent uncovering of several analytical relationships that provided significant insights into the forces and processes of population aging.

Early recognition of population aging occurred in France and Sweden in the late nineteenth century, at a time in which the proportions of the population aged 65 and over in both countries were approaching 8%. In 1900, Gustav Sundbärg, a Swedish researcher, conducted the first rudimentary comparative analyses of the age profiles of national populations. He calculated the proportions of population in three age groups – under age 15, 15 though 49, and 50 and over for several countries. In comparing the results, he found that most European countries had nearly 50% of their population in the age group 15–49, but differed markedly in the proportions at young and old ages. He speculated that countries would retain the same levels at adult ages, but would shift over time from having high proportions of young persons to high proportions of older persons.

This remarkable insight then led him to characterize national populations as gradually shifting from progressive (younger) to stationary and eventually to regressive (older) age structures. Moreover, he indicated that these shifts in the age structure of a population were due primarily to changes in fertility and mortality. Sundbärg can thus be credited with being the first person to conduct quantitative cross-national comparisons of changing levels of vital events and their effects on population structures that would lead inevitably to population aging. Moreover, by stipulating the roles of declining fertility and mortality, he anticipated the notion that came to be known later as the demographic transition.

Although some attention to the possibilities of population aging and accompanying fears of

depopulation was manifested in the recession period of the 1930s, especially in France and Great Britain, concerted research into the analytical aspects of the issue only began in the post-World War II period. In the early 1950s, several relationships and mathematical equations of fundamental importance to the demographic dynamics of population aging were introduced by demographers at the Population Division of the United Nations and Princeton University, most notably Jean Bourgeois-Pichat, Frank Lorimer, and Ansley Coale. The discovery of these equations, which unveil precise relationships among several elementary population parameters, put the demography of aging on a sound analytical footing.

Models of Population Dynamics

Using stable population equations first expressed by Lotka and co-workers in the early part of the twentieth century, these demographers began with an initial stable age structure, varied the fertility rates while holding mortality constant, and then compared the resulting stable age structures. With this comparative statics approach, they were able to isolate the effects of fertility declines on population age structures. Similar procedures were applied to examine the effects of changing mortality rates while holding fertility schedules constant. Three key findings relevant for the field emerged from these exercises.

One, Coale's research, in particular, showed that changes in fertility (e.g., in the birthrate) cause the entire age distribution to pivot about the mean age of childbearing. The mean age of childbearing is approximately equal to the mean length of generation, which is between ages 25 and 30 for most countries in the world. The pivoting of the age structure about the mean age of childbearing connotes that an increase in the birthrate, *ceteris paribus*, results in an increase in the proportion of the total population below that age and a decrease in the birthrate on the proportion above it. Thus, declines in the fertility rate, which have been observed in most of the world's populations in the past 30 years, lead to population aging.

A second major finding relates to the effects of changing mortality on age structure. Demographers have demonstrated that a mortality change with respect to age (measured by a log linear transformation that expresses the mortality rate decreasing by the same relative amount throughout the age range) has little or no effect on the age structure. Thus, mortality levels can change, albeit in a restricted form, and have no effect on the age distribution. In this specific case, the entire effect of the change is felt equally among all age groups resulting in no structural adjustment. The population growth rate may change, but not the age structure. Observed mortality declines in real populations, however, do not occur in such a simple pattern with respect to age. Instead, they are concentrated either between birth and early childhood or at ages 50 or 60 and above. Concentration of a mortality decline between birth and early childhood results in a younger age distribution; the effect of more infants surviving is analogous to an increase in the birthrate. Concentration of a mortality decline at later ages results in an older age distribution. The point at which a mortality improvement leads to an older, rather than a younger, population is marked by a life expectancy at birth of between 60 and 65 years.

A third finding was that fertility changes have far more influence on initial population aging than do mortality changes, a somewhat counterintuitive result now well known to demographers. Fertility changes have more initial impact because they are introduced into the age structure at a single point – age zero. In contrast, age-specific patterns of mortality improvement that are spread throughout the age range have offsetting effects with respect to age structure adjustment. As major declines in mortality levels shift from younger to older ages, as has been historically the case, mortality comes to play a major role in the population aging process. The effects of these transitions on age structure lie at the heart of what has been described as the shift from aging from the base (of the age distribution) to aging at the apex.

Formal demographic investigations carried out by Preston and associates in the mid-1980s on the relationship between intrinsic and actual population growth rates revealed further analytical insights into population aging. They showed that when the fertility rate drops to replacement level in a population closed to migration and remains there indefinitely, a condition corresponding to a total fertility rate slightly over two children per woman and an intrinsic growth rate of zero, the growth rate of the population below the mean age of childbearing is zero. This is an important insight into the forces of population aging because it implies, and in fact necessitates, that all future population growth beyond the time at which fertility achieves replacement level takes place in age groups above the mean age of childbearing.

Thus, after the fertility rate falls to replacement level, all subsequent growth is the result of growth momentum built into the age structure, and it occurs because already-born, large cohorts replace the smaller cohorts above the mean age of childbearing. The inevitable result of this growth of the middle and upper age population segments is rapid population aging. Moreover, in populations experiencing low and falling mortality (life expectancy exceeding 60 years),

the growth of upper age segments is enhanced because mortality reductions occur at ever more advanced ages. This results in steady gains in life expectancy and the growth of the oldest old population (85 years and over). The picture is much the same for both sexes, except that the relative survival of women is much greater than that of men, and as a group they usually experience more advanced population aging.

Population Aging Trends

World The world's population is aging rapidly and will continue to do so well into the twenty-first century. **Table 1** shows that the world's number of older persons 65 years of age and over more than doubled between 1950 and 1990 and is projected to reach over 809 million by the year 2025. The annual growth rate for the total population decreased slightly from 1.8% just after World War II to 1.7% in 1985–90, but is projected to fall to 1.0% by 2020–25. In contrast, the growth rate of the aged population moves in an opposite direction; it increases from 2.0% in 1950–55 to 2.4% in 1985–90, and continues to accelerate to a level of 3.0% annually in 2020–25. In terms of the two summary measures of population aging reported in the table (the percentage of the population age 65 and over and the median age) both show only a modest rise in the earlier period, but marked increases from 1990 onward. Within the aged population itself, the numbers of the oldest old, 80 years of age and over, have increased greatly. However, in the period ahead they will only increase marginally as a proportion of the total aged population. This reflects the large influx of the Baby Boom cohorts into the older ages in the second and third decades of the twenty-first century.

Table 1 Dynamics of world population aging, 1950–2025[a]

	1950	*1990*	*2025*
Numbers (1000s)			
Total aged	144 380	325 747	809 339
80+	15 853	53 692	135 923
80+ of total aged (%)	11.0	16.5	16.8
Indicators			
Percent 65+	5.1	6.2	9.7
Median age	23.4	24.2	31.0
Rates of growth			
Total	1.8	1.7	1.0
65+	2.2	2.7	3.0
65+ — total	0.4	1.0	2.0
Growth factors			
Total fertility rate	5.0	3.4	2.4
Life expectancy at birth	46.4	63.3	72.5
Infant mortality	155.0	68.0	31.0

[a] From *World Population Reports: The 1992 Revision*. New York: United Nations, 1993.

Population aging, as noted earlier, is the result of dynamic changes that have taken place in fertility and mortality levels. The total fertility rate, life expectancy at birth, and the infant mortality rate are commonly used by demographers to measure these levels. The total fertility rate decreased from five children per woman on average in 1950–55 to 3.4 in 1985–90, and is expected to decline further to 2.4 in 2020–25, according to these United Nations projections. World mortality rates also have improved markedly during most of the twentieth century, in spite of some countertrends in certain geographic regions (e.g., Central and Eastern Europe, and the former Soviet Union). The average life expectancy at birth increased between 1950–55 and 1985–90 by nearly 17 years to reach 63.3, and it is projected to reach 72.5 years by 2020–25. Declines in infant mortality accounted for most of the increase in life expectancy in the earlier period. In accordance with theoretical expectations, the proportion of aged persons was moderated in the period up to 1990 by large reductions in infant mortality, in spite of substantial declines in fertility. However, in the 1990–2025 period the sustained fertility reductions, even at lower levels, acting in concert with mortality reductions concentrated at later ages, will bring about major changes in the median age and percentage of older persons in the world's population.

Major Regions These observations for the world as a whole serve to illustrate the main dimensions of population aging, but they do not capture the major differences that exist between the world's major regions and the countries that they comprise. The demographic transition in vital rates from high levels of fertility and mortality to low levels has already progressed significantly in the more developed countries. The median age of the aggregated, more developed region was 33.6 years in 1990 and is expected to reach 39.8 by 2025. The percentage of population 65 years and over is slightly over 12% currently and will rise to 18.3% by the end of projection period. The current rate of growth of the older population in the more developed region will remain fairly stable at about 1.9% annually.

In contrast, population aging in the less developed region is far less advanced, with a median age of 22.0 years in 1990 and 4.5% of the population aged. These levels will increase to 29.6 years and 8.0%, respectively in 2025. The rate of growth of the older population will continue to accelerate from 4.5% currently to 8.0% annually in the period 2020–25. A majority of the world's aged already live in less developed countries (56.2%), and by 2025 nearly 70% of the 809 million older persons will live in this

region. This reflects the enormous population momentum that is built into the age structures and the changing vital rates for the less economically advanced countries. Truly, it is fair to say that population aging has become a worldwide demographic phenomenon.

Policy Implications

Demographers and other social scientists increasingly have been called upon to examine the consequences of the broad shifts in overall population structure brought about by population aging. Because of the seemingly irreversible nature of these developments, some observers have referred to them as a gerontologic revolution that brings about enduring societal changes in economic, social, and political structures. Forecasts inform us that the effects of population aging are expected to be particularly significant in the second and third decades of the twenty-first century, but it is important to emphasize that important changes already have occurred to alter the composition and age structure of the older population.

In the economic realm, attention has been given to the effects of population aging on rates of economic growth, aggregate savings, investments, consumption patterns, and labor supply. There is growing concern over the future capacity of state economies to maintain social security, health, and other entitlement programs at existing levels. Moreover, the labor force in many developed societies is continuing to age, therefore raising questions about potential labor scarcity, productivity, and appropriate retirement ages. These macroeconomic issues arising from population aging require demographic projections and integrated models to examine current trends and future scenarios (*see* Economics: Society).

There also are social and political implications of major importance. Many of these relate to changes in kin and family structures and intergenerational relations, a topic considered in a later section. Population aging affects roles, role transitions, and behaviors across the life course, as well as the expectations that individuals hold regarding their future lifetimes. The progressive aging of the voting age population in many countries, along with prevailing patterns of voting behavior, has raised concerns over the extent to which older persons may gain increasing influence in political spheres and the possibility of intergenerational conflict.

Demography of the Aged

The second major subfield directs attention primarily to the composition of the older population, how it changes over time, and the major dynamic factors that bring these changes about. The aged can be viewed as a particular subpopulation that has its own age, sex, and other defining characteristics. Like the total population, it is subject to change resulting from entrants (persons reaching the qualifying ages or moving geographically into the population); exits (persons dying or moving out of the population); and changes in the characteristics of the population through either volitional (e.g., persons marrying) or non-volitional shifts (e.g., becoming widowed).

If is often noted that turnover in the older subpopulation is usually greater than in the younger population because of the frequency of events that take place at these ages. For example, over three-quarters of the deaths occurring in more developed countries occur at ages 65 and above. Similarly, change is common in terms of working behavior, social relationships, onset of multiple chronic diseases, disability, living arrangements, and not infrequently in the economic conditions of later life. Thus, studying the dynamic changes in the composition of the older population and transitions occurring in the lives of older persons presents some challenging conceptual and methodological issues.

Population aging, as noted earlier, brings about increased numbers of older persons and generally increases the proportion they represent of total population. The momentum for the numerical growth emanates from the size of earlier birth cohorts and the survival that they have experienced. Thus, the great surge in the growth of the older population that can be expected in the second and third decades of the twenty-first century reflects the succession of large Baby Boom cohorts from the post-World War II period. Analyses of cohort succession, the dominant characteristics of these cohorts, and their likely effects on the composition of future older populations has been a very fertile field of recent demographic research.

Considerable attention has been given to the increasing demographic diversity found in this subpopulation. Among characteristic features that have been most often noted are the rapid growth of the oldest-old segments of the older population, the declining ratios of older males to females, and the increasing ethnic and racial makeup of the older population. These changes reflect not only cohort succession, but important changes that have occurred in levels of survival for subgroups in the older population. Mortality reductions continue to be experienced at the older ages, thereby raising life expectancies at even the most advanced ages. The trends in survival have been largely responsible for the growth of the oldest-old population, the most rapidly

increasing age group in most countries. An increasing number of research studies focus on this segment of the older population, for they are often the most in need of social supports and long-term care.

Finally, it should be noted that demographic studies of the geographic mobility of older persons continue to receive considerable research attention. Although levels of mobility among older persons are substantially below those of the younger population, the nature of the moves and their implications for older persons can be significant. Among the main types of mobility that have been examined are retirement moves, geographic relocations made to be closer to other family members, and moves into institutions and family households necessitated by health and other circumstances. These various types of moves have often proved difficult to measure, and concerted data collection efforts are currently being developed to assess their importance.

New Directions

Family Demography

A flourishing area of demographic research focuses on how population aging affects changing family structures and functions. The more generic term family is used to identify this subfield in order to encompass broad family features such as kinship structures and extended family relations, as well as the structure of households and dynamic aspects of intrafamily interactions. Demographers have been concerned with examining major trends and determinants in these dimensions across time and in different societal settings. The determinants of these trends that have been studied include not only demographic factors, such as changes in fertility, mortality, and geographic mobility, but also related social changes in family formation and marital patterns, labor supply, and preferences as they are shaped by cultural values and norms.

The family, as a major social institution, plays a central role in socialization, accumulation and allocation of resources, and provision of support and care for family members. The latter dimensions are particularly important in the case of families that contain older members in need of assistance. These functions are strongly influenced by structural features of the extended and nuclear family, household living arrangements, and interactions among family members.

Kinship Structures Formal demographic analyses, along the lines presented in the earlier discussion, have yielded some important observations about the effect of the main demographic changes on family structures. Declines in fertility naturally bring about smaller families and less extensive lateral kinship ties with siblings, cousins, and eventually with aunts and uncles. Lower mortality, especially concentrated at younger ages as it is initially, may counteract some of these tendencies. However, as mortality declines extend into the older ages, they increase the number of surviving parents for an adult child. Thus, there is greater vertical kinship. The result of changes in these two demographic parameters is the creation of what has been referred to as the 'beanpole' family, with greater numbers of generations made up of smaller-sized nuclear families.

A corollary of these developments reflects on the numbers, types, and durations spent in various roles over the life course. Because of less time spent in child rearing for a parent, greater durations of one's adult lifetime are spent with parents, and interestingly, a greater number of family membership roles will be experienced in a lifetime. Depending on the generation in question, older persons will have less younger relations, but younger persons will have more older relations. It is this paradoxical situation that contributes to the concern over the future burdens of caring for older persons if mortality continues to decline at advanced ages and fertility remains low or declines further.

These kin structures may differ significantly between rural and urban areas within countries; reflecting variations in the timing of changing vital rates and internal migration. They are also affected by sex differentials in mortality that lead to sex imbalances that favor female over male kin. However, in some Asian societies, such as China and Korea, sex selectivity in fertility favoring males through selective abortion may serve to counteract these imbalances over time.

Household Structures Household composition, which greatly influences the level of emotional, physical, and material support available to elderly persons, is formed from a constellation of kin and unrelated individuals. A trend reported for most countries in the world has been toward smaller household sizes. Lower fertility accounts for some of this decline, but it also can be attributed to shifting living arrangements away from coresidence of older persons with their adult children.

For many elderly persons, living arrangements are the single most important social structure governing their everyday lives. The term living arrangements is interpreted broadly and includes the full set of within-household social relationships, as well as the features and conditions of the dwelling units in

which households reside. However, demographers have devoted greater attention to the former considerations.

The most dominant trend in living arrangements among the elderly has been the steady increase in the proportions of older persons living with spouses and those who live alone, especially among widows, and declines in those living with children or other relatives. Trends in independent living by older intact husband–wife families are greatly affected by the improved joint survival of married persons up to and continuing into the later stages of life. For both intact nuclear families that contain older persons and for older unmarried persons, factors that have been found to be related to independent living are improved economic circumstances, better health and disability status, and declines in available kin, most notably children. Underlying these factors has been the implied desire for greater independence and privacy on the part of both older parents and their children. Recent econometric analyses suggest, however, that a downturn in the proportion of young-old widows (ages 65–74) living alone has occurred in the 1980s in the United States, mainly due to greater numbers of baby boom children who are themselves unmarried and in need of assistance in living accommodations. This suggests that trends in such arrangements as living alone are not unilinear, but are sensitive to cohort fluctuations in the number and demands of children, as well as the conditions of older parents (*see* Housing).

Coresidence is only one reflection of the ties that parents can have with their children. Indeed, it is often noted for developed societies that coresidence is much less common than in developing countries, but that close spatial residence may exist and communications and assistance and social support between kin may be very strong. Another feature of living arrangements that has been receiving increased research attention is the role that geographic mobility can play in altering the propinquity of kin. One way that this can be assessed is by the amount of travel time that it takes for a parent to visit a nearest child or vice versa. Recent examination of changes in these travel time differences among older persons indicate that they tend to decline over time (attributable mainly to geographic shifts) and that increased functional disability is associated with the probability and size of spatial convergence, especially for lower-income and ethnic groups.

Family Dynamics These basic analyses of kin and household structure have provided the groundwork for extensive research that has been undertaken on intergenerational flows of resources on both macro and micro levels. An important feature of recent demographic research in this area has been to examine intergenerational transfers and the decision-making processes underlying the use of resources.

The family plays a major role in the societal allocation of resources through such mechanisms as the creation of human capital, family labor supply, direct *in vivo* financial transfers, and bequests. But not all of these transfers are monetary or in goods, many are social support services, such as caregiving (either instrumental or expressive). Considerable research is underway that attempts to assess the amount of these transfers among household family members and across generations. Moreover, attention also is being given to larger societal accounting for all transfers including governmental transfers. Formal demographic analyses provide macroparameters for estimating the demand side of these equations.

On the micro level, there is considerable attention being given to intrafamily decision-making regarding transfers of various types. These social demographic studies are focusing on expectations that individuals have regarding future transfers, especially those relating to potential sources of care and other forms of support. Moreover, attention is being given to the likelihood of future survival, economic conditions, and possible future changes in living arrangements, such as movement into a nursing home. These research efforts directed to expectational data are not unlike those of earlier studies of expectations regarding fertility outcomes (e.g., ideal and expected family size) that demographers have developed. Surveys also have increasingly sought to obtain data from multiple individuals in a household, including spouses and other caregivers, that make it possible to examine the dynamics of the family interactions and decision-making. Moreover, many recent surveys involve longitudinal designs that make it possible to assess transitions in important dimensions of the lives of older persons.

Biodemography of Aging

A new direction of research that seeks to integrate more fully demography and the biological sciences has been termed the biodemography of aging. The fields of comparative population biology, population genetics, and epidemiology have long shared common perspectives and methodological approaches with the field of demography. For example, the stable population model discussed earlier has been widely used for studies of not only human populations, but those of other species as well. In turn, demographers have examined biological and genetic factors as possible explanations for fertility and mortality trends

and differentials (e.g., the effects of fecundity on fertility levels and genetic factors on sex mortality differentials).

Although the term biodemography was first introduced in 1949, the emphasis on the aging process accounts for much of the recent interest in this interdisciplinary perspective. The great gains in life expectancy that have been made in the last half of the twentieth century have raised important questions about the possible biological limits to human longevity, the factors that are involved in the observed deceleration of mortality rates at advanced ages, and how these changes affect the incidence and prevalence of chronic diseases and disabilities, especially among persons at older ages. To probe such questions requires deeper understanding of the complex, interrelated factors that underlie the disease, disability, and death processes.

A focus on aging and the aged population calls attention to a number of distinctive features of current developments: one, a majority of deaths occur at the older ages, with half of the female and one-third of the male deaths occurring at age 80 and above in developed countries. These deaths at older ages are mainly attributable to non-communicable chronic diseases with extended lifetime trajectories. Two, older persons are more likely to experience comorbidities, sensory deficits, and functional limitations that limit their capacity to fulfill the basic activities of daily life. Three, a broad range of factors can be identified that influence age-related changes in health and functioning, such as senescence, genetic predispositions, physiological states, nutritional status, physical and cognitive functioning, health behaviors, and medical care and other interventions. Thus, there is a rich set of conceptual issues that challenge interdisciplinary researchers in this subfield.

A broad range of data sources is being developed that will enable studies to be undertaken to address these issues. The first, surveys of older persons, including the oldest-old, are increasingly being designed to examine multidimensional aspects of the aging process. This includes clinical assessments of anthropometry, physical performance, cognitive status, blood chemistry, and genetic markers. Many of these surveys are longitudinal in design, which enable researchers to identify important transitions in physiological and psychosocial states and, thereby, examine causal relationships more precisely. Data from surveys are being linked to other sources of data (e.g., administrative records, death certificates) that make it possible to enrich analyses of outcomes and intergenerational patterns with more reliable data. Finally, many surveys are now national in scope and include samples of important subgroups in the population, such as minorities, women, and cohorts of persons at important transition points in the later life course (e.g., preretirement and retirement periods, the advanced ages of life).

Second, studies of twins are being expanded to provide natural experiments for examining the inheritability of longevity, frailty, and patterns of dementia across the life course and especially at older ages. These studies enable researchers to investigate the relative roles of genetic and environmental factors for measurable outcomes in the aging process. Multigenerational twin registers are being created in a number of countries, which will enable important comparative analyses to be undertaken (*see* Behavioral Genetics).

Third, animal colonies of mammalian and nonmammalian species already exist to study issues relating to aging, but there is a new emphasis on conducting research to examine age-related mortality, cause of death, and even disability processes using animal models. Understanding the demographic structures and dynamics of non-human species may offer important insights into aging processes in humans. There have been renewed calls for a more comparative emphasis in aging research to emphasize the place of humans in a larger mammalian demographic perspective. Animal models also offer the advantages of experimental designs for studying various interventions. An example of the latter is the large-scale programs to examine diet restriction and its effects on life extension (*see* Models of Aging: Vertebrates). Evidence suggests a deceleration in the rate of increase in mortality at the oldest ages for insect and human populations, perhaps due to heterogeneity at the cohort level, allowing only the heartiest to survive to the most advanced ages. Thus, Gompertz curves, which imply exponentially increasing rates of mortality with age, do not fit actual age mortality patterns at advanced ages for several species.

Demographers and other social scientists have been involved in a broad range of activities relating to the biodemography subfield. An important aspect of this effort involves the use of demographic analytic models for examining population structures and their dynamics. These include stable population models; actuarial procedures, such as the life table, multistate models, and hazard models; and multivariate statistical applications. Many of these tools are now being used to make forecasts of mortality, disease, and disability trends on a national level. Thus, the implications of population aging are being examined not only in terms of compositional changes, but also many dimensions of direct importance in determining appropriate societal responses

to the relative health and well-being of older persons. Simulation approaches also are used for examining the potential impact of various interventions on levels of these dimensions and their economic and social implications.

See also: Behavioral Genetics; Economics: Society; Housing; Models of Aging: Vertebrates.

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Dental Health

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Glossary

Abrasion – Physical wear of the teeth brought about by contact with objects other than food or other teeth.

Attrition – Repetitive tooth to tooth contact results in the loss of tooth tissue at the contacting surfaces.

Caries – A disease process where plaque has been allowed to develop for a period of time. Carbohydrates in food and drink are fermented by the microorganisms in plaque, which produce acid, resulting in the demineralization of teeth.

Dentures – Removable prosthetic appliances.

Erosion – Loss of enamel and dentine arising from chemical attack from sources other than chemicals produced intraorally by bacteria.

Periodontal Disease – A progressive, chronic inflammatory disease of the supporting tissues of teeth. Bacterial placque results in gingivitis or periodontitis.

Introduction

A functioning mouth is essential for the enjoyment of life in old age. The oral tissues undergo a number of changes with age. Dental disease is common in the elderly, although largely preventable. Replacing lost teeth is possible but is becoming increasingly technically demanding as patients' expectations increase. Diseases of the oral soft tissues are often found, and oral carcinoma is a major problem.

There is little doubt that the past two decades have seen an increasing amount of attention paid to the oral health of the elderly. This has come about because of the increase in the numbers and proportions of elderly persons, but also because of changes in disease patterns, patient expectations, and improvements in dental technology. Some older patients have perfectly functioning dentitions and to an

extent can be treated as perfectly normal patients, particularly if they are biologically young. However, many older patients have extensive dental disease, the treatment of which is complicated by oral age changes and systemic disease. Older dental patients may also suffer from cognitive deteriorations that may influence dental treatment. In some cases older adults may be accompanied by relatives or other caregivers who may act as patients' advocates to help explain procedures and treatment choices.

Total tooth loss (edentulism) is a significant finding in elderly patients throughout the world (**Table 1**). Edentulism is influenced not just by patterns and prevalence of dental disease but also by socioeconomic factors. In the more economically developed nations, the past few decades have seen a dramatic decline in edentulism. It is certainly true that denture wearing is much less socially acceptable and is no longer seen as an inevitable consequence of growing older. A number of pathologies are associated with denture wearing; these are discussed later in this article.

Periodontal disease is predominantly a progressive chronic inflammatory disease of the supporting tissues of teeth. It is initiated by the presence of bacterial plaque, which, in susceptible patients, may result in the development of gingivitis or periodontitis. Severe periodontitis may cause marked loss of the alveolar bone, which supports the teeth and, in some cases, may ultimately cause tooth loss. The prevalence of advanced periodontal disease in elderly patients varies from 5 to 70%. The risk factors and treatment modalities are discussed later.

Dental caries is the most prevalent disease in the world and is of significant economic consequence. Caries is a disease associated with sugar; it is much less prevalent in the developing world, where there is less intake of refined food. In elderly patients the incidence of caries varies widely and is associated with diet, socioeconomic status, and, most importantly, fluoridation of the water supply. A particular type of caries (root caries) is associated with elderly patients and is found at the gingival margins of teeth. It is associated with gingival recession, which is common in elderly patients. It is thought that the bacteria that are associated with this type of lesion are different from those causing caries on other tooth surfaces.

Most dental diseases are preventable, and strategies that minimize risk of disease should be universally employed.

There is some speculation about the effect of oral infection on cardiovascular disease. In particular, it is thought that periodontal disease may be a risk factor for the development of a number of conditions, including coronary heart disease, cerebrovascular disease, and diabetes. The results of these studies need to be treated with some caution; a causal link has yet to be proved but a linking pathogenesis has been proposed. This involves the presence of hyperinflammatory monocytes in susceptible individuals that react to the challenge of oral bacteria and that locally cause periodontal destruction and more distantly in the body cause changes that result in the aforementioned related pathologies.

Table 1 Prevalence of edentulousness of elderly in selected countries

Country	*Prevalence (%)*
Europe	
UK	46
Italy	19
Poland	25
Denmark	27
Austria	15
Americas	
Canada	58
United States	26
Asia	
India	19
Thailand	16
China	11
Malaysia	57

Data from the World Health Organization.

The Aging Mouth

The normal functioning of the oral cavity involves a complex interaction of a number of different systems. In order to chew, taste, speak, and swallow, all of the components of the oral cavity must work efficiently. To a considerable extent, facial aesthetics depends on a healthy dentition and its supporting structures. As we age, many of the components of the oral cavity undergo age changes. Some changes are caused by disease rather than by aging, and often it is difficult to make a distinction between the two. The teeth undergo a number of important changes in older individuals. Most changes, however, are related to physical-chemical processes and are not therefore true age changes. Tooth enamel undergoes changes in terms of its mineral content, and both fluoride and nitrogen content increase with age. This can be modified, however, in the presence of tooth wear or dental caries. One clinically important change is a gradual reduction in the size of the pulp chamber and an increase in secondary dentine. Another change in dentine involves a gradual obturation of the dentinal tubules leading to dentinal sclerosis. Cementum, which covers the roots of teeth, shows a gradual increase with age. Taken together, these changes are used in forensic dentistry to age unidentified

individuals. Oral mucosal thickness is reduced with age and in the tongue by about one-third from 20 to 80 years of age. This thinning of the oral mucosa (**Figure 1**) leads to underlying structures being more prominent; this is particularly true in the case of underlying vascular tissues and sebaceous glands. Sublingual varicosities are almost universally present in those over the age of 70 but are clinically unimportant except in terms of their recognition. In general terms, the microscopic appearance of the oral mucosa shows a simplification in structure with age, and the rete pegs/ridges are less well developed. The age changes in the oral mucosa may well make it more susceptible to noxious agents such as tobacco and alcohol and lead to the age-associated increase in oral cancer and precancer. It is often very difficult to differentiate the effects of disease and age in the oral mucosa. Many vitamin deficiencies are known to affect the oral mucosa, and these are more common in older age groups. It is often stated in medical and even dental texts that an inevitability of growing old is a reduction in salivary flow. This is erroneous – there is little evidence to suggest that in healthy elderly individuals saliva production from the major salivary glands is reduced. Certainly, structural changes with age are noted in the glands (**Figure 2**), including a reduction in secretory tissue, but this seems to have a minimal effect on actual salivary

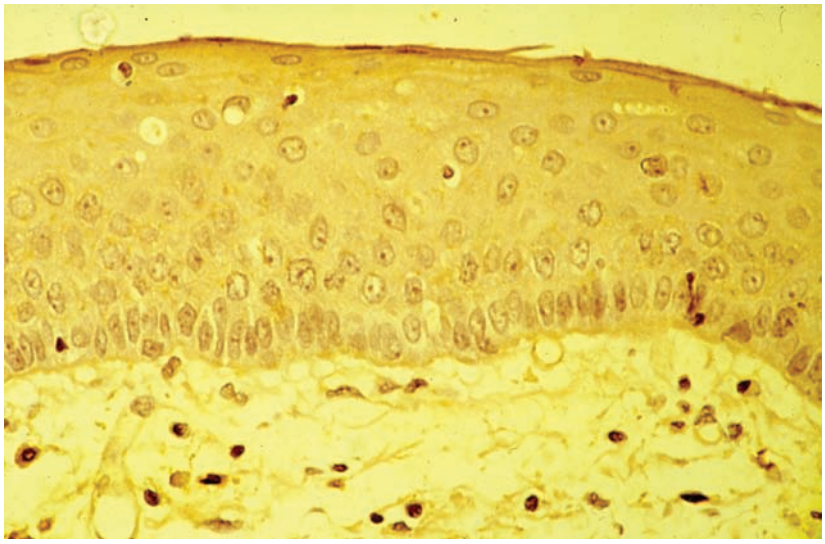

Figure 1 Thinning of the oral mucosa.

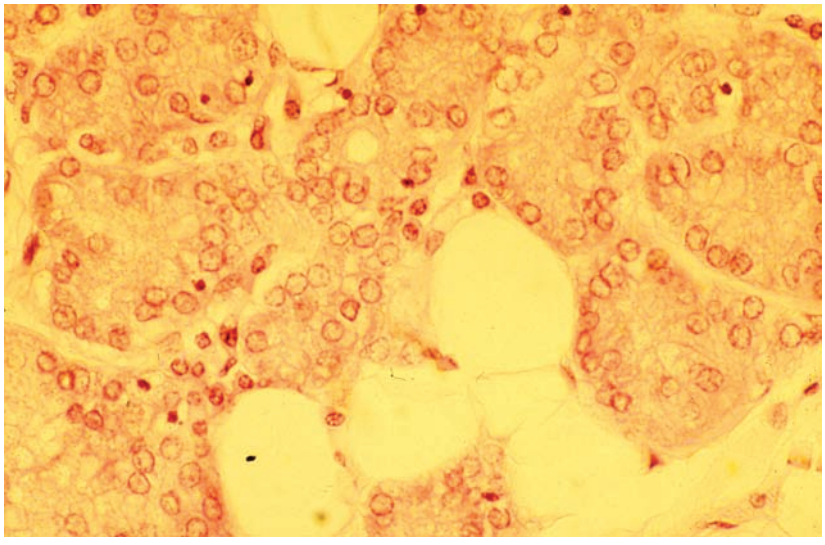

Figure 2 Structural changes with age in the major salivary glands.

production in healthy older individuals. It is thought that this is one example of a change with age that is compensated for by an increased efficiency of the remaining tissue, and the concept of a secretory reserve in salivary glands has been postulated. It is certainly true that many older patients have a reduction in salivary flow, but this is commonly caused by prescribed medication (see **Table 2**) that is common in this age group or the result of connective tissue disorders such as Sjögren's syndrome. Another cause may be therapeutic radiation therapy, although the more targeted treatment and better screening now available has reduced this problem. A reduction in salivary flow has a profound effect on oral health and will result in a dramatic increase in dental caries if aggressive preventative measures are not in place. Other problems associated with xerostoia are shown in **Table 3**. Oral/facial muscles are also affected by the aging process, and it has been shown that the bulk of the masticatory muscles reduce by up to one-third over an 80-year period. The retention of natural teeth and a normal diet throughout life almost certainly will mitigate against this in exactly the same way that exercise provides protection against aging in skeletal muscles. Electrophysiological studies show that there is a prolongation of the muscle contraction in older individuals. This combined with the loss in masticatory muscle bulk leads to a loss of precision of jaw movements, which is particularly relevant in denture wearers. Mandibular and maxillary bone shows variable osteoporotic changes with age, with mandibular bone density decreasing by 20% from 45 to 90 years of age. This change is not related to tooth loss and has been shown to progress independently.

Table 2 Main classes of drugs reducing salivary flow

Anticholinergic drugs, e.g., diuretics, antihistamines, antidepressants
Sympathomimetic drugs, e.g., bronchodilators, antihypertensives, antidepressants
Skeletal muscle relaxants
Antimigraine agents
Cytotoxic drugs
Opioids and hypnotics
Retinoids
Cytokines

Table 3 Problems associated with xerostomia

Increase in dental caries
Increased risk of periodontal disease
Oral mucosa more susceptible to injury
Difficulty with mastication
Speech problems
Dentures poorly retained

However, an important factor in the preservation of alveolar bone in the jaws is the retention of teeth and the absence of periodontal disease. In the absence of natural teeth there is a steady loss of supporting alveolar bone, which can make the successful wearing of dentures difficult. There is little evidence that the incidence of temporomandibular joint problems is independently associated with age. Masseteric muscle pain is commonly found in denture wearers where there is an excessively vertical jaw position.

Carious and Non-carious Tooth Tissue Loss

Teeth are both subject to the cyclic forces of mastication and exposed to a wide variety of chemical challenges during life. These ultimately result in the loss of enamel and dentine from the following processes:

- Attrition, in which repetitive tooth-to-tooth contact results in the loss of tooth tissue at the contacting surfaces from chemical attack from sources other than chemicals produced intraorally by bacteria (**Figure 3**).
- Abrasion, in which physical wear of the tooth is brought about by contact with objects other than a tooth, such as when using the teeth to open packaging or to hold objects such as nails, hair grips, or pen tops.
- Erosion, in which the loss of enamel and dentine arises from chemical attack from sources other than chemicals produced intraorally by bacteria. This distinguishes the erosive process from dental caries. The acid sources may be either intrinsic or extrinsic.

Any condition or behavior that results in acid from the gastrointestinal tract coming into contact with the teeth constitutes an intrinsic factor. This may be as a result of the following:

- Vomiting: When this is frequent, an organic or psychosomatic disorder may be the cause.
- Regurgitation and reflux: These are generally associated with increased gastric volume and pressure and could be a sign of an incompetent cardiac sphincter.

Three principal sources of extrinsic acid are identifiable:

- Diet: Principally acidic foods and beverages that are consumed frequently and in excess. These include carbonated beverages, citric fruit juices, sports drinks, certain herbal teas, fruits and berries, salad dressings, and vinegar conserves.

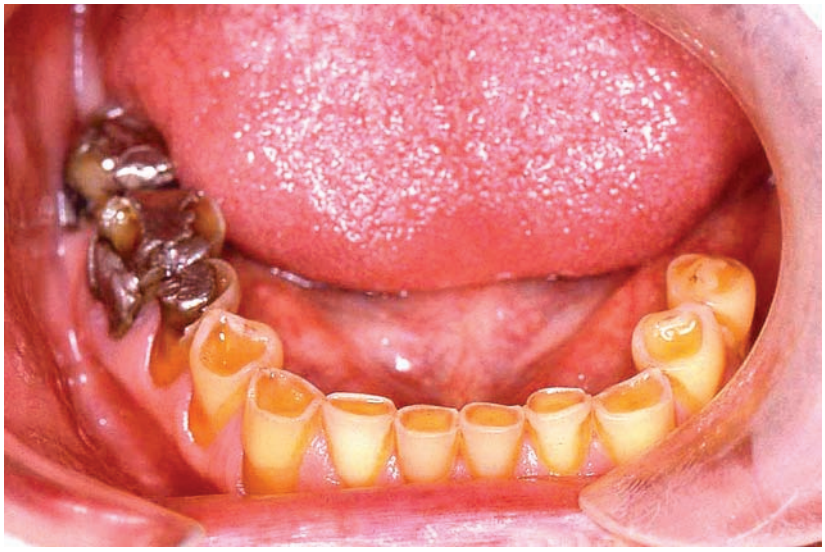

Figure 3 Loss of tooth tissue due to attrition and erosion.

- Medication: Any medicament that has a low pH that comes into contact with the teeth. Examples include chewable aspirin, iron tonics, and vitamin C.
- Environment: Principally exposure of the teeth to acid in the working environment. This includes workers in the printing, fertilizer, battery, and munitions industries as well as professional wine tasters.
- Dental caries: A disease process that can occur on any part of a tooth in the oral cavity where dental plaque has been allowed to develop for a period of time. Carbohydrates in food and drinks are fermented by the microorganisms of dental plaque. These produce acid as a by-product, and this, on coming into contact with tooth substance, brings about the demineralization of the surrounding tooth substance, thus initiating the carious process. A pH of less than 5.5 is required for demineralization of enamel to occur. In the case of dentine and cementum, the tissues attacked by root surface caries, the required pH is less acidic (6.2–6.7). Remineralization occurs when the pH is restored to neutrality as a result of the actions of the buffering capacity of the saliva and the availability of calcium and phosphorous ions at the tooth surface. Caries progresses when the equilibrium between demineralization and remineralization favors demineralization. This results in extensive tooth destruction (cavities) in which the dental pulp may become involved with loss of vitality and abscess formation of potential sequelae. Factors that favor demineralization are excessive and frequent intake of sugar, poor oral hygiene, and low salivary flow rate. A particular problem in elderly patients is root surface caries (**Figure 4**). Although the caries process on root surfaces is similar to that on the crown of the tooth, initiation and progression occur more rapidly. A prerequisite for this to develop is exposure of the root surface to the oral environment. This arises from the gingival recession that occurs with age, attachment loss, or exposure of the root to the oral environment from periodontal pocketing. Major factors determining susceptibility are a reduced salivary flow rate (such as a side effect of medication for a medical condition), poor oral hygiene, and a cariogenic diet. The institution of good oral hygiene and application of fluoride to the lesion may arrest the active lesion and obviate the need for restoration. An active root caries lesion usually spreads laterally and eventually, if left untreated, can encircle the tooth, culminating in tooth fracture. Restoration is possible in some cases but is problematic mainly due to impaired visibility and difficult access. These factors compromise the final restoration.

Modern dentistry seeks to prevent the loss of tooth substance from such processes before it occurs. Advising patients on the major causative factors and offering appropriate preventive advice is core to this goal. This should also involve liaison with other health-care professionals if appropriate. Dietary analysis and advice is a common preventive measure in the management of both dental caries (improve oral hygiene, reduce level and frequency of sugar intake) and dental erosion (reduce level and frequency of acidic food or beverage intake). In the case of attrition, it may be that wearing a hard splint at night, when grinding of the teeth is thought to occur, will prevent further tooth substance loss, as will the identification and elimination of a habit

Figure 4 Root surface caries.

(such as gripping nails with the teeth) when abrasion is suspected. When prevention fails and loss of tooth substance continues, restoration is indicated. The extent to which this is viable depends upon the residual quantity and quality of tooth tissue.

Active caries should be eliminated by conventional cavity preparation and restoration with an appropriate restorative material. The advent and application of adhesive restorative materials, such as resin composites and glass ionomer cements, have challenged the use of traditional restorative materials (such as amalgam and gold) in specialized circumstances. They can enable more tooth tissue to be preserved than older materials such as dental amalgam and gold. Glass ionomer cement is thought by many to be the material of choice for treating root caries, for it both bonds to tooth substance and has a caries inhibitory effect by virtue of its fluoride-releasing properties. Furthermore, research has shown that bacterial colonies fail to thrive on its surface, and, as a result, there is a high level of tolerance to this material displayed in the surrounding soft tissues. When the level of tooth destruction is greater, however, crowns may be necessary to restore both appearance and function. In all cases it should be borne in mind that the dental pulp may be diseased and root treatment may be necessary prior to the restoration of the tooth. Sometimes due to the inherent self-repair mechanisms of the tooth, namely, the laying down of secondary and tertiary dentine within the pulpal space, it is not possible to root treat the tooth, as access to the residual pulp has been obliterated.

Once provided, restorations have a finite life span and will ultimately fail, necessitating replacement or repair. The ability of the patient to maintain a satisfactory level of oral hygiene may decline with age and circumstance. The maintenance of good oral hygiene demands a high level of manual dexterity, which is even greater when complex cleaning regimes are required around crowns and bridges.

The ever-changing needs of elderly patients present a challenge to the restorative dentist.

The Periodontal Problem

Periodontal diseases are a group of multifactorial disorders that affect the supporting structures of the teeth. Inflammatory gingivitis and periodontal diseases are initiated by dental plaque, but the incidence, prevalence, and severity seen within both populations and individuals are not necessarily directly related to quantitative measures of deposits. This occurs because individuals have differing disease susceptibilities, with more severely affected individuals usually displaying one or more risk factors for the conditions.

Investigation of the role of age as a risk factor is not simple, as differentiating the effects of intrinsic aging and the effects of cumulative environmental challenge over many years is difficult. Study of the epidemiology of periodontal diseases is complex, and interpretation of it has been contentious. There is no doubt that age brings many changes to both the periodontium and the host responses to bacterial challenge, but the modern consensus is that age *per se* is unlikely to increase susceptibility to periodontal diseases. The problem, however, is that around 75% of persons aged over 65 years suffer from chronic disease, and affected patients are often

treated with multiple prescribed medications. These factors may result in deficits in general dexterity, coordination and mobility, and reduced mental capacity, which in turn may have direct and indirect negative effects on the periodontium. Undesirable effects from medications include xerostomia, increased bleeding tendency, and gingival overgrowth, and clinicians must have an understanding of these issues if adequate treatment is to be provided.

The Scale of the Problem

Edentulism is declining and life expectancy is increasing, and these facts combine to lead to increased demand for periodontal treatment in the elderly. Fortunately, if an elderly patient has retained teeth into old age, this implies that the individual is not highly susceptible to periodontal disease, which improves periodontal prognosis. Periodontal therapy can and should be provided for elderly patients whenever possible.

Periodontal Management

Clearly all necessary dental management must be provided, but this section concentrates upon the periodontal aspects only.

It is essential that periodontal therapy is tailored to the individual needs of the older patient. Dentists are trained to try to achieve periodontal health, defined by lack of bleeding on probing and manageable probing depths, as the treatment outcome. This is the laudable ideal, and where possible should be the goal of treatment. However, in some circumstances, for example, when an individual patient cannot maintain plaque levels below his or her individual disease threshold, achieving periodontal health is not an attainable objective. From the patient's perspective, having a comfortable, functional, and aesthetically acceptable dentition may be the desired treatment outcome. Therapy that meets these requirements, even if not achieving periodontal stability, should not be regarded as inadequate and in some circumstances is entirely appropriate.

Detailed medical, dental, family, and social histories should be recorded and regularly updated. Patients who are confused or who have poor memory may be unreliable historians, but it is essential that the dentist has access to all relevant information if safe and effective treatment is to be planned and instituted. Clarification of the facts may have to be sought from other health-care professionals and family, though consent must be given for such approaches to be made. A periodontal diagnosis should then be produced, followed by an individually designed treatment plan. At this stage it may be clear whether attaining periodontal stability is an attainable treatment goal.

Minimizing bacterial load through a combination of both thorough mechanical therapy and improving plaque control is usual, and a non-surgical approach is commonly adopted. Some elderly patients may require extra support, including provision of additional or modification of existing hygiene aids, but advancing age *per se* does not necessarily result in reduced self-care capacity. Powered toothbrushes may be helpful, though heavy or bulky models are not advised. Chemical plaque control using twice daily 0.2% chlorhexidine gluconate mouthwash may be appropriate for a very small number of patients who are incapable of achieving adequate physical plaque control, though this should be a very carefully considered last option, as the disadvantageous side effects usually outweigh the advantages. Root surface instrumentation should ideally be restricted to removal of plaque and calculus so that removal of the fluoride-rich outer root surface is not removed. This precaution is advised because of the increased prevalence of root caries with age. Application of fluoride to treated surfaces and provision of dietary advice are useful preventive measures.

Reevaluation following completion of cause-related therapy is essential. Three main outcomes are then possible:

1. If the therapy has resulted in stability, an individually designed maintenance program is required, as the patient has not been cured. Many elderly patients respond very well to simple nonsurgical therapy as can be seen in **Figures 5** and **6**.
2. If disease is still present, a careful appraisal of the cause of treatment failure is mandatory. If the cause is not identified and rectified (the most common being inadequate plaque control), any subsequent treatment is likely to fail. If elimination of the cause of failure is possible and is in accordance with the wishes of the patient, cause-related therapy may be performed again with a reasonable chance of success. Periodontal surgery, if indicated by the clinical examination, may be undertaken with a good chance of success, provided that there are no medical contraindications and the plaque control is adequate. Pocket elimination surgery is best avoided in favor of flap surgery to reduce root exposure due to the root caries risk. Stabilization is followed by maintenance.
3. Treatment failure due to causes that cannot or will not be rectified requires a pragmatic approach. The patient's wishes are very important. Research suggests that on average, teeth require bone support covering at least one-third of the root length to preserve adequate function. If it is judged, given the

Figure 5 Patient before beginning a course of non-surgical therapy.

Figure 6 Patient from **Figure 5** after a course of non-surgical therapy.

average life expectancy, that there is sufficient remaining periodontal support, palliative periodontal care, comprising regular professional scaling and polishing, may be instituted, though if adverse signs or symptoms subsequently appear, extraction of the affected teeth may be the only option. If it is judged that there is insufficient remaining periodontal tooth support, extraction and possible tooth replacement must be considered.

Treatment Options for Missing Teeth

It is common knowledge that people do not always retain all of their natural teeth into old age. When some or all of the natural teeth have been lost, elderly people may wish to explore the options for their replacement. Replacement options are considered separately for the partially dentate (people who have some natural teeth remaining) and for the edentulous (people who have no natural teeth remaining).

The Partially Dentate Person

In an elderly person who retains some of their own teeth, the loss of others may impact on either their appearance or function. The loss of anterior teeth will usually cause the elderly person to seek treatment because of unacceptable aesthetics. In contrast, they may be unconcerned about the loss of some of the posterior teeth unless they perceive their masticatory ability to be compromised. There are a

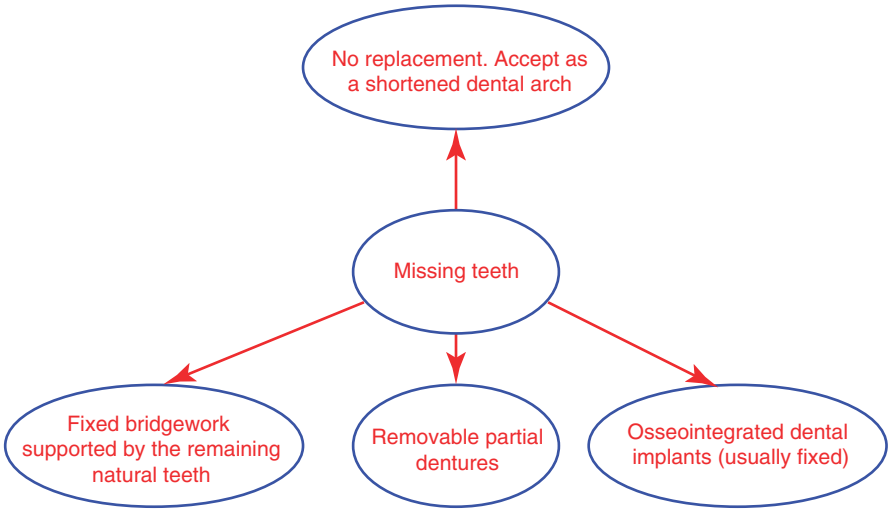

Figure 7 The main options for the replacement of missing teeth in partially dentate people.

number of possibilities for replacement (**Figure 7**). These are not mutually exclusive options, and in some situations a combination of approaches may be needed.

Fixed Restorations Many people will seek replacement of their missing teeth by dental restorations that are fixed to structures in their mouth. The main advantage of this approach is that it can permit function with the replacement teeth similar to when the natural teeth were present. There are two ways in which the missing teeth can be replaced. The first approach is to use fixed bridgework, in which the replacement teeth attach to the natural teeth adjacent to the missing teeth. Since this approach uses the adjacent teeth as abutments, it is more commonly used when there are only a small number of missing units and the spaces between the natural teeth are not too large. Traditionally this type of treatment has been carried out by removing part of the structure of the adjacent abutment teeth so that the restorations incorporating the replacement missing teeth can be cemented to these. There are a number of materials that can be used to construct bridgework, but all need to have sufficient strength to withstand the high forces that are applied during mastication. This type of approach may be contraindicated if the abutment teeth are heavily restored because of previous dental disease, because there may no longer be sufficient tooth structure to support the masticatory loading that would be directed onto the fixed bridgework.

A particular disadvantage of the traditional fixed bridgework approach for the replacement of missing teeth is the need to remove significant amounts of enamel and dentine from the abutments. For this reason, techniques have evolved that have allowed a much less invasive approach. It is possible to bond bridgework to the abutment teeth using adhesive materials without needing to remove more than very minimal amounts of tooth tissue. However, this approach is usually not possible when the teeth adjacent to a space have been damaged by dental caries that has resulted in the replacement of a large part of their structure with dental restorations.

The second approach to replacing the missing teeth is the use of osseointegrated dental implants, which are surgically placed into the bone of the mandible or maxilla in the region where the teeth are missing. Replacement crowns can then be subsequently constructed and attached to the implants (or in some cases removable dentures can be constructed that are attached to them; see later). This technique is becoming increasingly used as a first-line treatment modality for people who have a small number of missing teeth, provided that the remaining dentition is in good condition. There are some anatomical factors that may restrict the location of where the implants can be placed. The success rates of this approach are generally high, but factors such as smoking may compromise this.

Partial Dentures This treatment modality involves the construction of removable prosthetic appliances. This may be the only realistic treatment modality for people with very few remaining natural teeth. The advantage of using removable prostheses is that this line of treatment is non-invasive to the remaining tissues of the mouth. However, they are generally more obtrusive than fixed restorations, as they usually have to cover a much broader area of the oral tissues (**Figure 8**). Partial dentures can be particularly useful when the long-term prognosis of some of the

Figure 8 A removable partial denture.

remaining teeth is unclear, as they can be planned so that they can be modified if circumstances change. However, some groups of elderly people, such as those with dementia or other neurological conditions, may have particular difficulties in wearing partial dentures. Such an approach may therefore be contraindicated for these groups of people.

Non-replacement of Missing Teeth It may be a perfectly acceptable option not to replace the missing teeth. This concept is sometimes referred to as the shortened dental arch. It is unlikely to be acceptable to elderly people if anterior teeth are missing, due to concerns about appearance, but may be quite appropriate if only posterior teeth are absent. It is apparent that many people with lost and unreplaced posterior teeth are able to adapt their chewing and function with the teeth that remain. People with such reduced dentitions may still have more than adequate masticatory ability.

Maintenance One major issue concerning the replacement of missing teeth in the elderly is that of keeping the remaining teeth and oral tissues healthy. A high standard of oral hygiene is required to ensure that plaque is adequately removed around fixed restorations. If this is not carried out effectively, it may result in failure of the restorations and loss of further teeth. Even though assistive devices or professional support may be available, the ability to maintain an adequate standard of oral hygiene can become more difficult in the elderly, who may have problems such as poor vision or reduced manual dexterity (e.g., due to arthritis). Furthermore, some medical conditions and the use of certain therapeutic agents can affect salivary flow, which may result in the remaining dentition becoming very susceptible to further plaque-induced disease. For this reason, very careful deliberation is required when considering even the use of removable partial dentures, as well as the more advanced treatment options such as bridgework or implants. There is a need for meticulous hygiene around any type of bridgework or implant-supported restorations. It can be very difficult to maintain a high standard of oral hygiene if elderly people have compromised vision or because of loss of manual dexterity due to tremors or other neurological conditions. Care workers might be able to assist such people, but they must be effectively trained to do so.

The Edentulous Person

Improvements in oral health may mean that a significant proportion of people will be able to retain at least some of their teeth for all of their life. However, some people may be rendered edentulous because of the effects of oral disease (**Figure 9**). Most edentulous people will wish to have their teeth replaced, and this is usually carried out by the provision of removable complete dentures. The ability of patients to wear complete dentures successfully may depend on a number of factors, including the anatomical form of the maxillary and mandibular alveolar ridges, the general health, the salivary flow, and the motor skills required to control the dentures during oral function. It can be difficult for some elderly people to adapt to complete dentures if they are introduced to them at a very advanced stage of their lives. Nevertheless, many patients do manage to acquire the skills

Figure 9 An edentulous maxillary ridge.

Figure 10 Osseointegrated implants in the mandible.

necessary to function with complete dentures successfully. When difficulties arise, they appear to be much more common with mandibular dentures that replace the missing lower teeth.

There are some groups of elderly people who may experience major difficulties wearing complete dentures. Neurological conditions such as Parkinson's disease or strokes may severely compromise motor skills, which may result in the individual having great difficulty in functioning effectively with complete dentures.

The use of osseointegrated implants to stabilize complete dentures (**Figure 10**) has been a major advance in improving oral function in edentulous elderly people. The most common treatment modality is the placement of two implants, one on each side of the mandible, to which a lower complete denture can be attached. The prosthesis is removable, which means that it is more straightforward to keep the implants clean than it is with fixed prostheses.

It may be simple for care workers supporting elderly edentulous people to help maintain their tissue health by means of good oral and denture hygiene. However, it should be emphasized again that care workers should be effectively trained in such procedures, particularly when removable complete dentures are worn over osseointegrated implants.

Oral Surgery for Elderly Patients

Oral surgery for elderly patients may be straightforward or more complicated. A number of local oral factors may complicate matters, but the medical health of patient is a vital factor. Elderly patients are often taking multiple drug regimes, which, along with the presence of the common diseases of old age,

may complicate surgery. Older patients surprisingly often require the removal of retained teeth, commonly the wisdom teeth (third molars),which may cause a problem at any age. Even those who appear to be edentulous may in older age have wisdom teeth erupting. Often retained wisdom teeth may be incidental radiographic findings and if symptomless and showing no cystic change or causing damage to adjacent teeth may be left untreated. In some elderly patients, erupting wisdom teeth may present with acute or chronic infection, and a surgical removal of the tooth is required. Other teeth less commonly retained in elderly patients include lower premolars and upper canines. These are often symptomless, and surgical intervention is only required in the minority of patients. Retained roots may cause no symptoms or may require surgical removal if infected or causing pain. A very common surgical problem in older patients is denture-induced hyperplasia. This is usually the result of damage to the oral soft tissues caused by patients wearing ill-fitting dentures that should have been replaced many years previously. Commonly hyperplastic tissue is found in the vestibular areas of both jaws and in the palate (**Figure 11**). It is often sensible to radically adjust the denture prior to surgery to reduce the size of the lesion. Pre-prosthetic surgical procedures including ridge augmentation and implants may significantly improve the prognosis for elderly denture wearers. Facial fractures in elderly patients who are involved in trauma are common because of osteoporosis of the facial bones. The reduction and fixation of these fractures may be complicated by the increased risk of infection and decreased facial blood supply.

Health of the Oral Soft Tissues

It is vital that health-care professionals are able to recognize normal oral mucosa. This is particularly

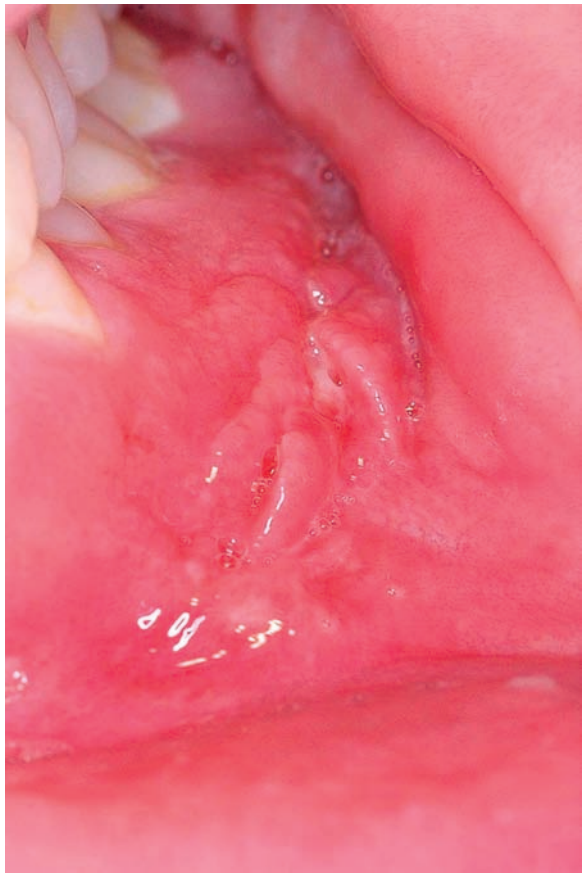

Figure 11 Hyperplastic fibrous tissue in the buccal sulcus.

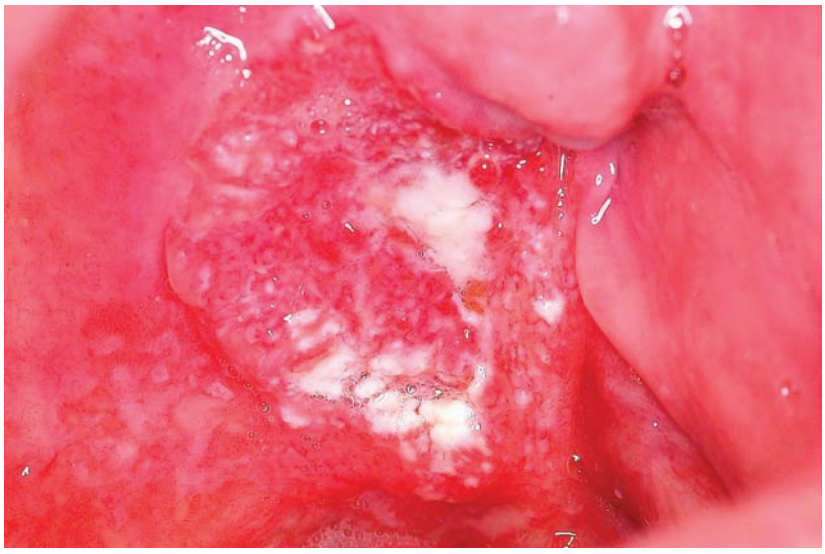

Figure 12 Oral carcinoma.

Table 4 Diseases of the oral cavity seen in older patients

Infections
Chronic atrophic candidosis
Chronic hyperplastic candidosis
Acute pseudomembraneous candidosis
Acute atrophic candidosis
Herpes zoster (shingles)
Oral manifestations of dermatological diseases
Lichen planus
Mucous membrane pemphigoid
Pemphigus
Oral mucosal malignancy/premalignancy
Leukoplakia
Erythroplakia
Submucosal fibrosis (rare except in Asia)
Oral carcinoma
Malignant melanoma (rare)
Pleomorphic adenoma (major and minor salivary glands)
Adenoid cystic carcinoma (more common in minor salivary glands)
Lymphoma (rare in mouth but more common in parotid gland)
Miscellaneous conditions
Black hairy tongue
Geographic tongue
Traumatic ulceration
Denture-induced hyperplasia
Aphthous ulceration
Lingual varicosities
Traumatic keratosis
Amalgam tattoo
Burning mouth syndrome
Trigeminal neuralgia
Oral manifestations of Paget's disease
TMJ pain/syndrome
Mucocele (of minor salivary glands)

important in older individuals, in whom certain normal anatomical features, including prominent sebaceous glands, lingual varicosities, and lingual papillae, may be mistaken for disease. By far the most important of the non-dental diseases affecting the oral soft tissues is squamous cell carcinoma. There is a steady increase in the incidence of oral carcinoma (**Figure 12**) after midlife, and the disease is predominantly found in males. Survival rates remain modest and the 5-year survival rate, although site dependent, can be as low as 50% even after aggressive surgical, chemotherapeutic, and radiological treatment. There is evidence that survival rates are relatively age independent and that staging, site of tumor, therapeutic regime used, and general health are much more important determinants of outcome. There are a number of distressing consequences of the treatment of oral cancer, including xerostomia, trismus, loss of hard and soft oral tissues, aesthetic problems, and mucositis. The aesthetic and functional replacement of soft tissues may be challenging for both patient and practitioner. Risk factors include smoking and alcohol consumption. In some parts of the world (e.g., India), oral squamous cell carcinoma is particularly common because of betel nut chewing and reverse smoking habits. Premalignant lesions of the oral mucosa are also found in older patients; these may require monitoring over a number of years with periodic histological assessment. Oral lichen planus can be seen in older patients, particularly on the tongue and buccal mucosa. It is controversial to suggest that oral lichen planus is associated with transformation to oral cancer. There is little evidence to suggest that, in the absence of other risk factors, oral lichen planus leads to oral cancer but it should be routinely monitored. Other oral diseases that may be seen in elderly patients are summarized in **Table 4**.

See also: Caregiving and Caring; Diet and Nutrition; Smell and Taste.

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Depression

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Glossary

Anhedonia – Loss of interest or pleasure in daily life.

Bereavement (also called Uncomplicated Grief) – Response to the loss of a loved one or valued possession such as one's home.

Bipolar Disorder (also called Manic Depressive Disorder) – Depression cycles with periods of excessive optimism, elation, and activity.

Depression – Disorder of mood characterized by cognitive, affective, and somatic or vegetative physical symptoms. Key characteristics are an overwhelming sense of despondency or discouragement, and/or lack of interest in or enjoyment of everyday life.

Dysthymia – Defined by the presence of one of the two defining symptoms plus at least two other symptoms of depression continuously for at least 2 years.

Introduction

Depression is the single most common emotional disorder in all age groups: as many as 14% of US citizens will experience major depression at some point in the life cycle. Although some forms of depression are no less prevalent among older than among younger adults, the disorder has more profound implications for the elderly by virtue of its strong links with physical illness and impaired function, cognitive decline, impaired overall quality of life, and even mortality. As recently as 30 years ago, little was known about the prevalence or manifestations of late-life depression. There is now, however, a substantial research literature on depression among the elderly, describing its epidemiology, its diagnostic differentiation from other physical and emotional comorbidities, and its sometimes unique presentations and outcomes in older as compared with younger adults.

This article provides an overview of current knowledge of depression in late life, beginning with a brief review of the epidemiology of depression, in terms of its population prevalence both overall and with specific respect to older adults. Key diagnostic issues that complicate identification, classification, and treatment are then discussed, followed by an overview of risk factors for depressive disorders in late life. Current trends in pharmacological and non-pharmacological treatment are then highlighted, with special emphasis on so-called second-generation treatment problems that typically emerge in primary care settings.

Epidemiology and Significance

Depression is a disorder of mood characterized by cognitive, affective (emotional), and somatic or vegetative (physical) symptoms. Its key characteristics are an overwhelming sense of despondency or discouragement and/or lack of interest in or enjoyment of everyday life. Persons with diagnosable depression may experience sadness, tearfulness, feeling of worthlessness or guilt, difficulty concentrating and making decisions, changes in appetite and energy levels, physical restlessness or retardation, and sleep problems. Unlike the normal day-to-day fluctuations of moods we all experience, clinical depression is persistent and pervasive, lasting weeks, months, or even years.

It is now well established that major depressive disorder (MDD), as defined by the *Diagnostic and Statistical Manual*, 4th edition (DSM-IV; see next section for more information), is no more prevalent in the elderly than in persons under the age of 65. In fact, major depression is most common in adolescence and early adulthood and declines thereafter, yielding a point prevalence of 3–5% across the adult life span. Prevalence among older adults living independently in the community is, if anything, slightly lower than this. However, rates of MDD climb sharply as one moves from the general population of older persons to those with acute or chronic illness. It is quite common among older persons in acute hospitals and postacute rehabilitation settings, and even more so among those receiving long-term residential care. As many as one-quarter of cognitively intact nursing home residents suffer from a MDD. Furthermore, less severe depressive syndromes are quite common among older adults, affecting about 25% of individuals regardless of their health status or living arrangements. Hence, depression at some level affects a broad spectrum of older adults, particularly those who are ill or disabled.

These figures are chilling because of the implications of depression for health and well-being in late life. Ill health and functional disability are clearly risk factors for depression, but depression also increases the risk of incident health problems and functional decline. Depression intensifies illness symptoms and exacerbates suffering. It impairs cognitive function and may in fact place persons at risk of dementia. Although mechanisms are unclear, depression is also clearly associated with increased risk of mortality among older adults. In short, depression is a significant problem that compromises quality of life for older adults and may hasten physical decline and death.

There is reason to believe that rates of late-life depression will rise as the current cohort of middle-aged adults – the Baby Boomers – move into their later years. Compared with that group, the current generation of elderly, who came of age during the Great Depression and World War II, has displayed consistently lower rates of depression and other psychiatric disorders across their adult years. A number of reasons for this have been offered, including greater resilience of the 'great generation' and lowered inhibitions against reporting and seeking treatment for emotional distress among younger cohorts. Whatever the cause, it is probable that the prevalence of late-life depression will increase in coming years and that record numbers of older adults will seek treatment for depression during the coming decades.

Diagnostic Issues

Depression is not a monolithic disorder. Rather, it presents in a variety of syndromes that may vary in severity, length, and association of depression with other symptoms. A number of ongoing controversies attend identification and differential diagnosis of depression in late life. This section considers three such issues: common clinical syndromes and diagnoses, major versus minor depressive syndromes, and the question of whether late-life depression is qualitatively different from depressive syndromes at younger ages.

Diagnosing Depression: Common Clinical Syndromes

A constellation of mood disorders, many of them involving depression, are identified by DSM-IV. The key symptoms that are used to diagnose various depressive disorders appear in **Table 1**. In brief, *major depression* is characterized by presence of at least five of these symptoms, including one of the defining symptoms (depressed mood, loss of interest/pleasure), at least all or most of the time for 2 weeks or more. Major depression is most often observed as a single episode or as a series of such episodes; the latter is termed *recurrent* MDD. However, major depressive symptoms may also be present in at least two other disorders. First, in *bipolar disorder* (formerly manic-depressive disorder), depression cycles with periods of excessive optimism, elation, and activity. Bipolar disorder appears to be far less common in older than in younger adults, but it is unclear whether this reflects a true difference in lifetime prevalence across cohorts or simply a change in how the illness manifests in later life. Second, when major depression is accompanied by delusions and/or hallucinations, it is termed *psychotic depression*. Older adults with MDD are far more likely than younger persons to present with psychotic symptoms, particularly delusions. It is nonetheless a relatively rare manifestation, affecting only about 0.1% of elderly community residents.

Even when depressive symptoms are severe, the older individual may not actually be suffering from MDD. Grief reactions are a good example. *Normal bereavement*, also referred to as *uncomplicated grief*, is a response to loss of a loved one or even a valued possession such as one's home. Symptoms of depression are normal and understandable reactions to such losses, but usually resolve within about

Table 1 Symptoms of depression

Defining symptoms

1. Depressed mood: most of the day, nearly every day. May be established by self-report or by observation made by others (e.g., crying, tearful).
2. Loss of interest or pleasure (anhedonia): markedly diminished interest or pleasure in all or almost all activities most of the day, nearly every day. May be established by self-report or by observation made by others.

Additional symptoms

3. Significant weight loss or weight gain: change of 5% or more in body weight in 1 month or decrease or increase in appetite every day or almost every day.
4. Insomnia or hypersomnia nearly every day.
5. Psychomotor agitation or retardation: every day or almost every day. Must be observable by others, not just subjective feelings of restlessness or slowing down.
6. Fatigue or loss of energy every day or nearly every day.
7. Feelings of worthlessness or guilt: every day or nearly every day. Guilt must be excessive or inappropriate, not merely self-reproach.
8. Diminished ability to concentrate or indecisiveness every day or nearly every day. May be established by self-report or observation.
9. Recurrent suicidal ideation: recurrent thoughts of death or wish to die without a plan, or a suicide attempt or specific. Not just fear of death.

Adapted from *Diagnostic and Statistical Manual,* 4th edition. American Psychiatric Association, 1994.

6 months. In a very different vein, depression may also be caused directly by physiological effects of a medical condition unrelated to emotional processes or functions. Such syndromes, termed by DSM-IV as *depression due to a general medical condition*, are characterized by the same symptoms as, and hence may be difficult to differentiate from, MDD or other depressive disorders. There is some reason to believe that these syndromes are more common among the elderly, if for no other reason than the higher prevalence of many depressogenic diseases in later life.

Major versus Minor Depression

As noted earlier, the majority of older adults who suffer from depression experience lower-level symptoms that do not meet diagnostic criteria for MDD. The DSM recognizes several well-defined disorders that are considered minor depressive states. *Dysthymia* is defined as presence of one of the two defining symptoms plus at least two other symptoms of depression continuously for a period of at least 2 years. This chronic, low-level depression typically manifests relatively early in life and is in fact less prevalent in older than in younger persons. However, in a significant number of elderly adults with dysthymic disorder, the syndrome first occurs in middle or late adulthood. This form of dysthymia is less frequently preceded by a major depressive episode and is less likely to be associated with a comorbid personality disorder. In fact, some experts maintain that late-life dysthymia is a disorder qualitatively different from that seen in younger people. Lower-level depressive syndromes may also be a maladaptive response to emotionally distressing circumstances, as in *adjustment disorder with depressed mood*. These reactive depressive symptoms may or may not meet diagnostic criteria for MDD but usually resolve as the individual copes with or adapts to the precipitating event.

These clearly diagnosable disorders cannot account for the majority of non-major depressive syndromes that affect older adults. In fact, the majority of older persons with clinically significant depression may *not* meet diagnostic criteria for MDD, dysthymia, or other DSM-defined disorders just reviewed. These individuals nonetheless have significantly compromised quality of life because of their depressed mood. The prevalence of these less severe forms of depression has generated a great deal of interest in describing and defining *subsyndromal* depression among older and younger persons alike. Although some early research suggested that non-major depressive syndromes may be qualitatively different from MDD, the general consensus at present is that they simply represent one point along a continuum of depressive symptomatology. From this perspective, both minor depressive disorders and subsyndromal depressive symptoms are simply a lower-level manifestation of the same basic cognitive, affective, and physiological processes that underlie MDD, psychotic depression, and other more severe unipolar depressions.

This view of depression as a continuum of symptoms and severity is upheld by a number of lines of evidence. For example, both diagnosable and subsyndromal minor depressions are clear risk factors for development of MDD. They have neuroanatomical characteristics similar to major depressive syndromes and generally respond favorably to the same treatment regimens. Development of a major depressive episode is gradual and may present as a minor or subsyndromal depression in its early stages. Similarly, some apparently lower-level depressive syndromes may represent partial remission or the process of recovery from a more severe depression.

At this point, there is no consensus about how to define subsyndromal depression, and no clear distinction of subsyndromal depression from diagnosable minor depressive illnesses. Nor can researchers or clinicians reliably determine whether subsyndromal symptoms are prodromal to a full-blown major depressive episode. What is agreed upon is the fact that these lower-level depressive symptoms, previously believed to lack the clinical significance to merit diagnosis and treatment, in fact seriously impair quality of life among older adults. Reflecting this realization, the DSM now recognizes subsyndromal depression as a potential diagnosis under the 'not otherwise specified' rubric, and there is some impetus to add it as a distinct syndrome when the manual is next revised.

Is Late-Life Depression Different from Early or Midlife Syndromes?

It was previously noted that various depressive syndromes may be more or less common and may manifest somewhat differently in the elderly as compared with younger adults. This raises the more general question of whether depression in late life is qualitatively different from earlier-onset disorders. Three lines of evidence have fueled discussion of this issue. One concerns the unique presentation of depression among some older adults, in terms of the complex of symptoms characteristic of the disorder. A second has to do with the association between depression and cognitive impairment. The third, perhaps best

summarized in terms of early versus late-onset depression, draws from studies of the neuroanatomical characteristics of late-life depression.

Depressive Symptomatology in Late Life Although many older adults may present with the classic defining symptoms of depression, others may experience significant symptomatology in the *absence* of the sadness and discouragement that are considered central to identifying depression in younger adults. Depression without sadness is now a recognized syndrome among older adults, in whom hopelessness, helplessness, and anhedonia (loss of interest or pleasure in daily life) may be more common than outright despondency. Alternatively, some older adults may, like children and adolescents, display anger or irritability in lieu of sad mood.

Anxiety often co-occurs with depression across the life span, and differential diagnosis of depressive versus anxiety disorders can be challenging. This is particularly true among older persons, in whom symptoms are often so intertwined as to confound attempts to differentiate anxiety from depression. Although depressed older adults may display generalized anxiety, their worries frequently center on common problems of aging – to wit, physical health and cognitive function. Some older people may be reluctant to disclose feelings of depression to providers, instead presenting with somatic complaints that substitute for or mask depression. This is not to imply that the physical health complaints of depressed older persons are not real. Rather, depression may foment preoccupation with existing, very real health problems and accentuate the suffering that accompanies them. Alternatively, particularly in the primary care provider's office, older adults may focus on vegetative symptoms of depression, describing them in lieu of emotional distress. The picture is further complicated by the fact that many diseases may themselves trigger depressive symptoms (see next section), as may medications used to treat common disorders of aging. Hence, it can be difficult to distinguish physical from psychological processes. This clearly complicates diagnosis of depression in this age group; careful probing and analysis are recommended when the elderly person presents with multiple physical complaints.

Depression and Cognitive Function Complaints of memory problems are also associated with depression in complex ways. There is some natural confounding of depression and cognitive functioning, inasmuch as difficulty concentrating and making decisions are among the symptoms used to diagnose depression in any age group. Furthermore, depression itself may produce some cognitive slowing, particularly when the task involves executive function – that is, planning and coordination of complex activities. This is also true throughout the life span. But for older persons, this co-occurrence of mood and cognitive disturbances presents unique diagnostic difficulties, as it is possible that cognitive symptoms stem not from depression but from real memory disorders. Alternatively, the cognitive slowing common in depressive disorders may be misinterpreted as indicating a true dementing disorder in the phenomenon known as pseudodementia. The key characteristic of a true pseudodementia is its reversibility: When the depression remits, the cognitive problems also resolve. But there is also a clear association between depression and real (irreversible) cognitive deficits ranging from mild cognitive impairment to profound dementia. This association is not a straightforward one, however. It is manifested in a number of different ways and involves several independent dynamics.

First and most generally, depression is far more prevalent among persons with Alzheimer's disease or other dementias than in cognitively intact elders. In Alzheimer's disease, which is characterized by gradual and insidious onset, depression may be prodromal to incident cognitive impairment, occurring in the early stages of the disease and reflecting the individual's awareness of and emotional reaction to early signs of memory loss. As the disease progresses, and particularly as the individual loses the ability to express him- or herself verbally, it becomes more difficult to assess depression and differentiate it from the apathy and flatness of affect that typify dementing illness itself. However, depressive symptoms are generally most predominant in the early and middle stages of the disease and lessen as the individual's self-awareness wanes.

There is also some evidence that one or more episodes of major depression may increase risk of cognitive impairment later in life. Data on this point are just beginning to accrue, but it currently appears that some cognitive symptoms accompanying a major depressive episode may not resolve when the depression remits. Even when cognitive symptoms do remit in tandem with the depression, persons who suffered MDD with comorbid cognitive impairment are at increased risk of developing dementia over the next 5–10 years. In fact, incidence of diagnosable dementia is significantly greater in persons with a lifetime history of MDD, regardless of age at onset or of presence of cognitive symptoms. It thus appears that depression per se may place people at increased risk of developing dementing illness in late life. At

this point, however, the mechanisms of this effect are unknown.

Early- versus Late-Onset Depression Thus far, our differentiation of depression in late life from syndromes seen in younger persons has concentrated on symptomatology. However, this focus on overt manifestations begs the question of whether late-life depression is in fact the same disorder as that seen in non-elderly individuals. For the most part, attempts to link late-onset depression (first episode occurring at age 60 or later) with unique syndromes or histories have yielded little more than the broad descriptions just reviewed. However, a growing body of research using neuroimaging techniques suggests that at least some late-onset depressions have a unique neuroanatomical etiology that may be specific to old age. Specifically, these studies have identified a relatively consistent set of alterations in brain structure that accompany late-onset MDD and have linked these structural changes to some of the distinct patterns of symptomatology reviewed earlier.

Magnetic resonance imaging (MRI) studies indicate that this unique late-onset syndrome is characterized by numerous small hyperintensities – areas of brightness on the scan – that are thought to represent effects of ischemic vascular disease in subcortical structures of the brain and their frontal lobe projections. Although these lesions are not sufficient to cause the kind of functional changes associated with more dramatic vascular breakdowns such as stroke, they are closely linked with a unique syndrome that has come to be termed *vascular depression*. Vascular depression is characterized clinically by apathy (also termed lassitude in this context), psychomotor retardation, and particularly the executive dysfunction syndrome described earlier; vegetative symptoms are less common than in other depressive disorders. Persons with vascular depression tend to be functionally more impaired than elders with a recurrent early-onset depressive disorder and are at greater risk of further functional decline. They also respond less well to pharmacological treatment.

The body of work on functional neuroimaging in late-life depression is less well developed. However, if one borrows from age-non-specific studies, a coherent picture begins to emerge that bolsters clinical and structural support for the vascular depression hypothesis. There is good evidence that late-life depression is accompanied by decreased global cerebral blood flow and poorer activation in response to cognitive stimuli. As with younger adults, this is particularly evident in the prefrontal cortex. Global suppression of glucose metabolism is another common finding, specifically with respect to dorsal neocortical structures. In contrast, and perhaps reflecting a reciprocal relationship, ventral limbic structures associated with emotional function are hypermetabolic among depressed individuals.

Research on vascular depression is in its early stages. The literature cannot yet speak definitively to causal relationships among risk factors, neuroanatomical changes, and observed affective, cognitive, and behavioral symptoms identified thus far. However, it is clear that this syndrome is both unique to late life and qualitatively different from early-onset depressive disorders.

Risk Factors for Depression in Late Life

Biological Risk Factors

Depression in late life is closely linked with senescence at a very basic level. Before discussing medical illness and disease processes, however, it will be helpful to review some more basic processes that may trigger, or at the very least exacerbate, depression through biochemical or neuroanatomical mechanisms. A noticeable omission in the following discussion is the role of genetic factors in late-life depression. Although evidence is scant, there does seem to be a familial risk for late-onset depression. However, genetic risk factors appear to play a lesser role here than in early-onset disease and probably act through their association with other disease processes.

Cerebrovascular Factors As previous discussion of vascular depression implies, changes in brain structure and function related to vascular pathologies are a strong risk factor for incident depression. Interestingly, there is little empirical support for a direct link of late-onset depression with general vascular risk factors such as hypertension. This may, however, be due to the very small number of tightly controlled research studies examining this phenomenon. There is nonetheless strong evidence that subcortical hyperintensities are strongly linked with late-onset MDD and that depressive symptoms are well predicted by the site and size of observed lesions. A number of structures and processes related to frontal lobe function appear to be involved in vascular depression. In addition to white matter hyperintensities, identified structural markers include decreased volume of limbic and basal ganglia structures, including the hippocampus, amygdala, anterior cingulate gyrus, caudate, and the putamen; increased metabolism in areas of the limbic system; and decreased

metabolic activity in dorsal neocortical areas and the basal ganglia.

Whereas the lesions responsible for vascular depression tend to be relatively small and diffuse, other, more specific neurological dysfunctions may produce depression as well. Perhaps the most obvious and most heavily studied is *stroke*. Of persons in acute hospitals or in-patient rehabilitation for stroke, almost 20% meet criteria for MDD and an equal number experience minor depressive symptoms. Although functional deficits contribute to depression among stroke patients, there is now good evidence that structural damage to the brain is a causal factor, particularly in the months immediately preceding the stroke itself. Studies seeking to identify specific sites that are most closely associated with poststroke depression have yielded mixed findings, but the bulk of evidence implicates left anterior cortical and basal ganglial lesions. Poststroke depression is especially insidious because, unless aggressively treated, it impairs both the pace and final outcome of rehabilitation.

Endocrine Function It is well documented that depression is associated with abnormalities of hypothalamic–pituitary–adrenal (HPA) axis activity across the life span. This is most easily observed in high rates of hypercortisolemia, reflecting hypersecretion of corticotrophin releasing factor (CRF), among depressed individuals. Although research directly linking HPA axis function with depression in older adults is limited, they may be especially vulnerable to this dynamic because of increased sensitivity of adrenocorticotropin to the effects of CRF. Levels of dehydroepiandrosterone (DHEA) are lower in older than in younger adults; this pattern is associated with depressive symptomatology as well. Normal age changes in sleep patterns and sex hormones are also linked with HPA axis activity and may dispose some older adults to depression. There has as yet been little integration of these kinds of findings into a comprehensive model of stress response in late-life depression. However, this is a promising avenue for future study.

Medical and Clinical Risk Factors

It is well substantiated that ill health is a strong risk factor for both incidence and persistence of depression in late life (and, for that matter, across the life span). However, there remains some controversy about mechanisms underlying this association. At issue are two primary questions. First, is the correlation between depression and ill health driven by specific disease processes or by overall medical burden? Stated otherwise, do depression and medical conditions share common biological mechanisms, or does depression stem from cognitive and emotional reactions to overt illness symptoms, their effects on functional ability and/or implications for longevity? A second, orthogonal question is that of causal associations between depression and ill health. It was long assumed that the association of physical and mental health problems was driven by the former – that is, that people were depressed because they were sick. An emergent literature suggests, though, that the reverse is often equally true. These two questions form the basis for the following review of patterns of comorbidity of depression with other medical illnesses and of the role of functional disability and other illness symptoms in fomenting those patterns.

The Relationship of Specific Medical Conditions with Depression The list of specific disease processes that are known to be associated with depression is quite long, but for only a few has the link been definitively shown to derive from basic biological dysfunctions. Even for those conditions that have been identified as having an independent association with depressive symptomatology (i.e., net of other health conditions), dynamics of the relationship are not yet clear.

Cardiac disease provides an excellent example of the dilemma facing those who would parse the association of depression with ill health in late life. Depression is a frequent concomitant of heart disease, including acute conditions such as myocardial infarction (MI) as well as congestive heart failure (CHF) and other chronic heart problems. Persons who are not depressed at the time of an acute episode are at high risk of developing depression over the coming year. Those who are depressed at illness onset tend to remain depressed, to experience greater (cardiac) disease-related morbidity, and to be at greater risk of mortality due to the illness. A variety of shared biological mechanisms may account for these effects, including dysfunctions of the neuroendocrine and sympathetic nervous systems, immune dysfunction and consequent susceptibility to inflammation, poor adherence to medical regimens, and, of course, the cerebrovascular dysfunctions described earlier. In some cases, depression may represent a response to the stress engendered by an MI and its implications for mortality. However, there is now ample evidence that the association between depression and cardiac disease is bidirectional. That is, depression is equally as much a risk factor for subsequent heart disease as vice versa.

A handful of other health problems has been shown similarly to bear a mutually influential relationship with depression, such that depression either

predisposes individuals to incident disease or causes exacerbations and poorer prognosis of existing disease. The best documented examples are *diabetes, cancer, stroke, primary sleep disorders*, and *Parkinson's disease*, although the bidirectionality of the latter association is just beginning to be explored.

It is also important to note that many treatments for physical health problems may cause depression as well. A number of medications commonly used by older adults have been shown to cause depressive symptoms. These include (but are not limited to) selected anticonvulsants, flouroquinolone antibiotics, antihypertensives, anti-Parkinsons medications, barbiturates, benzodiazepines, beta-blockers, calcium channel blockers, narcotics, some non-steroidal anti-inflammatory agents, and steroids.

Overall Medical Burden and Depression Beyond this handful of disorders, there has been very little attempt to trace associations between medical disease process and depression systematically. There have, however, been a number of epidemiological surveys linking a range of disorders to depression. Interestingly, results have fairly consistently indicated that it is the number or severity of comorbid health problems, rather than the presence of any specific disorder, that predicts depression. Older adults with a greater number of health problems, or whose medical conditions are relatively more serious, are at substantially greater risk of depressive symptomatology regardless of the specific medical illnesses in question. Several phenomena may account for this effect.

Most obvious is the increased risk of functional disability that attends multiple medical comorbidities. Of all risk factors for late-life depression, impairment of basic and instrumental activities of daily living is the strongest and most consistent predictor. Large epidemiological surveys nearly universally have shown that the association of depressive symptoms with any given health problem, or with overall burden of illness (number and severity of comorbidities), can be wholly explained by the functional impairment associated with physical health problems. But as with the specific disorders just discussed, the relationship in question is a complex one. Disability can obviously cause emotional distress due to limitation of one's ability independently to conduct necessary daily activities. However, it is equally true that depression causes disability not only cross-sectionally, in the form of so-called *excess disability* due to lack of motivation or interest in activities, but also over time. Even controlling for medical status, depressed older adults are at much higher risk of incident functional disability than their non-depressed peers. It is as yet unknown whether this effect of depression upon subsequent functional status is caused by atrophy of functional abilities due to disuse or by effects of depression upon neuroendocrine and immune systems. Both paths likely play a part.

Disability is perhaps the most common, but certainly not the only, illness effect associated with late-life depression. In fact, any symptom that compromises continued daily function may predispose individuals to depression. Perhaps the most common symptom, after disability, is pain. A substantial proportion of older adults suffer to some extent from persistent pain due to osteoarthritis and other chronic illnesses. Over the past two decades, evidence has accrued documenting the strong association between chronic pain and depression in older adults. Causal associations among pain, depression, and disability remain a matter of dispute and likely vary with specific illness dynamics. Nonetheless, there is solid evidence that, as with other health processes, the relationship between pain and depression is mutual. Pain causes persons to become depressed, and depression both exacerbates the suffering attending physical pain and disposes individuals to increased pain and pain-related disability over time. The latter is a particular concern because older persons' pain, whether acute or chronic, is often underdetected and undertreated. Failure to control this very common illness symptom may thus place older adults at risk of a downward spiral of pain, depression, and disability.

Psychosocial Risk Factors

Psychosocial risk factors include external events and conditions, as well as behavioral, cognitive, and emotional responses to them, that make people vulnerable to emotional distress. Perhaps the largest broadly defined category of psychosocial risks for depression are factors that produce stress: enduring or transitory situations whose demands on the individual exceed his or her perceived ability to manage them. Those demands may in turn arise from characteristics of the situation itself, the individual coping with it, or other people or circumstances relevant to the situation. More pragmatically, primary psychosocial risk factors for depression include major and minor stressors, inadequate cognitive and behavioral coping skills, and lack of social resources for managing the situation.

Only a few of these types of risk factors are unique to late life. However, a number of stressors are more common among the elderly simply because they are normative for that stage of the life course. For example, many major life stressors are more common

in later life, e.g., death of a spouse or other loved one, one's own or a family member's severe illness, and retirement. Similarly, chronic illness and functional impairment, again more common in late life, often produce chronic stressors such as transportation problems for persons who do not drive or the high cost of prescription medications for chronic health problems. Coping resources may also be curtailed in late life. Social support – presence of one or more individuals who offer direct help or emotional nurturance – is an extremely important resource for coping with stress and for emotional well-being in general. Social isolation and loneliness are strong, consistent predictors of depression across the life span. Yet here again, many older adults may have lost or find it difficult to maintain contact with supportive friends and family members. In short, although the dynamics are much the same as earlier in life, the fact of aging itself may put older adults at increased risk of depression due to psychosocial circumstances.

Cognitive and behavioral strategies for coping with stress also differ among older as compared to younger adults. In particular, strategies for maintaining a sense of personal control over life circumstances – and hence, for interpreting them as benign or challenging rather than as inherently stressful – tend to shift in later life toward less direct, more self-focused efforts to manage one's response to events rather than the events themselves. This shift from primary to secondary control strategies – that is, from direct attempts to change the situation to self-management to control its effects – can be adaptive if coping attempts fit the circumstances. In particular, as objective opportunities for exerting direct control over life circumstances dwindle, it may be most beneficial to compensate by adapting one's own expectations of or responses to the situation. This sort of cognitive, behavioral, and affective flexibility is a crucial means of warding off the feelings of helplessness that predispose people to depression. In contrast, failure to make the shift to secondary control tactics or appropriately to evaluate the demands of the situation for direct versus indirect coping efforts can exacerbate stress and its effects.

Treatment of Late-Life Depression

It is now almost axiomatic that late-life depression is underdetected, underdiagnosed, and undertreated. Although this basic fact has not changed, there has been tremendous progress over the past 10 years in ensuring that older adults with depressive disorders are in fact appropriately assessed, triaged, and provided adequate treatment for their symptoms.

Pharmacological Treatment

As recently as 20 years ago, drug treatment of late-life depression was a somewhat risky business. Tricyclic antidepressants (TCAs), though effective in alleviating symptoms, often produced undesirable and even dangerous side effects due to their marked anticholinergic effects. However, with emergence of the selective serotonin reuptake inhibitors (SSRIs; e.g., citalopram, paroxetine), serotonin-norepinephrine reuptake inhibitors (SNRIs, e.g., venlafaxine), and other new-generation medications (e.g., bupropion), pharmacological treatment of depression in the elderly has become a less daunting enterprise.

Rigorously controlled studies of the effectiveness of antidepressants for treating late-life depression are surprisingly few, owing both to underrepresentation of older people in clinical trials and to ethical constraints against using a placebo condition. The efficacy of TCAs is nonetheless fairly well established, and a handful of studies have compared those medications with SSRIs as well. Serotonin system agents have generally proven no more effective than proven TCAs such as nortriptyline. However, their more benign side effect profile has made SSRIs the drugs of choice in first-line treatment of late-life depression. A number of different SSRIs have been proven effective in treating late-life depression. There is at present no strong evidence in favor of any one of the SSRIs for use with older adults. Similarly, although evidence is sparse, there is nothing to suggest that either TCAs or SSRIs are more or less effective than the newer selective norepinephrine reuptake inhibitors or combined serotonin–norepinephrine system agents.

Perhaps the more important choice in treating late-life depression is not selection of a specific medication, but structuring of the overall treatment regimen to improve chances of remission and prevent relapse. Because much pharmacological treatment occurs in the primary care context, depressed elders may not receive state-of-the-art treatment for their symptoms. In fact, it has been estimated that 40–45% of elderly antidepressant users may be on a suboptimal treatment regimen. For example, the 'start low, go slow' adage is always recommended when initiating pharmacological treatment of older persons, but existing evidence recommends titrating up to standard adult therapeutic dosage for optimal response. In practice, however, many older persons receive subtherapeutic dosages for the duration of treatment. Follow-up of elderly primary care outpatients may also be fragmented in terms of monitoring not only response but also compliance. In particular, many patients may discontinue medications when

symptoms begin to remit, placing themselves at high risk of relapse or recurrence. At present it is recommended that maintenance therapy continue for at least 6 months to ensure that symptoms do not recur.

When prescribing and monitoring meet best practice standards, about 60% of older adults with MDD respond to initial pharmacological therapy. This is comparable to rates among younger individuals. However, older persons may take longer to show improvement in symptoms and are more prone to relapse if and when treatment is discontinued. Overall, etiology of depression does not appear to be a strong factor in treatment response. The one exception to this rule is vascular dementia, which is more refractory than other syndromes and may require more prolonged treatment to achieve gains in quality of life. It nonetheless does respond to antidepressant medications, as does depression accompanying stroke, Parkinson's disease, and Alzheimer's disease and other dementias. Minor and subsyndromal depressive symptoms also respond well to pharmacological treatment. Just as depression is associated with incident cognitive and function impairment, as well as mortality, drug treatment has been shown to ameliorate health and functional consequences of depressive illness in older adults. Hence, particularly when symptoms are severe, aggressive pharmacological treatment, coupled with careful monitoring and follow-up, is essential.

Other Treatment Modalities

Although carefully controlled trials are relatively few, various forms of psychotherapy have proven useful in treating late-life depression. Perhaps the most heavily studied is cognitive-behavioral therapy (CBT), which has been proven to relieve depressive symptomatology in several studies with relatively healthy community-dwelling elderly. Although CBT and interpersonal therapy (IPT) are the most heavily studied forms of talk therapy for older adults, several other approaches have also yielded positive outcomes, including problem-solving therapy, psychodynamic therapy, and life review or reminiscence therapy. Although evidence is quite limited, group approaches appear to be as effective as one-on-one psychotherapy for cognitively intact elderly.

Psychotherapy appears to be equally effective for treating depression among cognitively intact older persons as among middle-aged adults and is generally recommended for use in similar ways. Specifically, for persons with severe depression, psychotherapy alone is not recommended; medication is usually needed to achieve marked remission of symptoms. However, talk therapy can be effective as an adjuvant treatment and may be central to maintaining treatment gains and preventing relapse in MDD. In contrast, for non-major disorders, psychotherapy may be all that is needed to achieve remission of symptoms.

Electroconvulsive therapy (ECT, or shock therapy) fell into popular disrepute for a number of years. With refinement of therapeutic methods and indications, however, ECT has become a very useful approach for treating severe or refractory depression. At present, older persons are disproportionately referred for ECT. Factors contributing to this include the greater prevalence of psychotic symptoms among elderly as compared with younger depressives, inability of some older persons to tolerate side effects of antidepressant medications, and vulnerability to health complications of depressive symptoms such as inactivity or self-neglect. As with other aspects of depression treatment, carefully controlled trials of the safety and efficacy of ECT for older adults are few. However, existing evidence shows good results in terms of remission of symptoms following ECT and few lasting side effects. In particular, there appears to be little grounds for concern about incident or exacerbated cognitive symptoms following ECT. Hence, for elders who are unable to profit from other forms of treatment, ECT may be a reasonable alternative.

Summary

In summary, as many as 40% of adults may suffer some form of depression during their later years. Although many of the risk factors for late-life depression parallel those for young-adult manifestations of the disorder, older persons may be at higher risk simply because of the circumstances of aging: increased risk of health and functional problems, greater exposure to some stressors, and shrinking resources. On the other hand, some older persons are at risk of late-onset depressive disorders due to aging of the brain. Regardless of etiology, late-life depression is a serious medical condition that demands treatment to avoid not only prolonged distress but also incident disability and further health problems. With appropriate treatment and monitoring, however, depressed elders can safely be restored to good mental health and prolonged quality of life.

See also: Bereavement and Loss; Cognitive-Behavioral Interventions; Disability, Functional Status and Activities of Daily Living; Psychological Well-Being; Reminiscence; Social Networks, Support, and Integration; Suicide.

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Diabetes

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Glossary

Metabolic Syndrome – Involves markers of inflammation associated with diabetes, hypertension, and stroke.

Noninsullin-Dependent Diabetes Mellitus (also called Type 2 Diabetes or Adult Onset Diabetes) – A chronic disease of insulin resistance and glucose intolerance contributing to vascular aging.

Introduction

Diabetes is a common disorder. The earliest known record of diabetes is mentioned on third dynasty Egyptian papyrus in 1552 BC. Polyuria was recognized as a symptom. In the first century BC, the Roman philosopher Arateus called diabetes "the melting down of flesh and limbs into urine." Galen labeled diabetes a kidney disorder. By the sixteenth century, Paracelsus had recognized diabetes as a serious general disorder.

The French physician Bouchardat recognized 135 years ago that cases of glycosuria were resolved during the siege of Paris in the Franco-Prussian War. The nineteenth-century Italian diabetelogist Catoni locked up patients to enforce dietary compliance. New approaches are being developed, but treatment problems continue and treatment outcomes are unclear for elderly diabetics.

Non-insulin-dependent diabetes mellitus (NIDDM), type 2 diabetes, also known as adult-onset diabetes, is a generally incurable chronic disease causing multisystem failure. NIDDM is part of the larger picture of insulin resistance and glucose intolerance contributing to vascular aging. Mechanisms for this association are being elucidated. Just as glycemia can be treated by diet, so can the vascular issues. For example, Biosphere 2 was a 3.15-acre ecosystem of energy and fuel production with recycled air, water, and organic material. When a shortfall occurred with replenishing atmospheric gases, participants were forced into extended caloric restriction. As a result, the blood pressure, cholesterol, and body weight of the participants significantly improved. These are all risk factors for vascular aging. The biosphere study suggests that caloric restriction may prevent vascular aging and reverse the metabolic syndrome, but lifestyle changes of this magnitude are rarely sustained and recent studies question what diet is best.

One reason the general public continues not to understand the pathogenesis of NIDDM relates to the fact that diabetes was first recognized as an acute process of fluid loss, not chronic degeneration. The first insulin preparations were developed in 1922. However, it was not until 1959 that a distinction was made between type 1 diabetes and NIDDM. NIDDM affects 90% of diabetics, causes most age-related pathology, and usually progresses insidiously. As the population ages, NIDDM prevalence will increase. In addition, diabetes prevalence is increasing worldwide, and repercussions for older adults have yet to be evaluated.

Epidemiology and Mortality

Mortality

Of the four most common causes of death, three relate to diabetes because insulin resistance contributes to diabetes and to death from heart disease and stroke. Diabetes, by itself, is the fourth leading cause of death for people aged 64 to 74 and for those aged 75 to 84. Diabetes is the sixth leading cause of deaths after age 85. Cardiovascular disease, usually congestive heart failure, causes death in 60 to 80% of diabetics. Diabetes increases mortality from acute myocardial infarction, acute stroke, and peripheral vascular disease. Other risk factors, including smoking and dyslipidemia, amplify diabetes mortality rates.

Epidemiology

Currently, 18.2 million Americans have known diabetes, 4 million are undiagnosed, and 60 million have the metabolic syndrome. Diabetes is a disease of the elderly; prevalence increases with aging. In the Framingham cohort, 30–40% of those over age 65 were glucose intolerant. The Honolulu Health Study found that high prevalence of diabetes and impaired glucose tolerance continue beyond age 75. Up to 20% of those over age 80 are diabetic, but studies on non-White groups such as African Americans, Hispanics, and American Indians, who appear to have higher prevalence, are limited. Public health implications are great, since a few years ago there were more people alive at age 80 than in all of history. Among those admitted to nursing homes, 26.2% had diabetes.

Diabetes and obesity have reached epidemic levels in Western and developing countries. There are 1.8 million diabetics in Britain – an increase of 400 000 since 1996. Worldwide, the number of people with diabetes is expected to rise from 171 million in 2000 to 366 million in 2030. In countries such as China, where the prevalence of diabetes was 0.6% in 1980, starvation has been resolved. Now 200 million Chinese are overweight, and diabetes prevalence has ballooned. On the South Pacific island Nauru, the inhabitants historically ate bananas, yams, and coconuts and were totally free from diabetes. When the population became wealthy from phosphate deposits, the islanders switched to a diet of refined flour, sugar, and processed vegetable oils. Up to one-half of the urbanized Nauru are now diabetic. In the United States, the overwhelming majority of diabetic children had type 1 disease; only 1 to 2% had NIDDM. Recently, however, 8 to 45% of newly diagnosed children have NIDDM.

In 1962, J. V. Neel proposed a thrifty gene that preserves extra dietary calories as fat during times of relative plenty to better survive times of famine. The full import of such a gene for aging is still unclear. Such genes become more common by natural selection. In the face of current plentiful foods, people with this gene are prone to obesity and diabetes. Natural selection against a thrifty gene is weak because detrimental effects do not occur until late in reproductive life.

Risk Factors

Insulin Resistance Glucose clearance by peripheral tissues is slowed for up to one to two decades before NIDDM develops in older people.

Family History Prospective studies show that insulin resistance predicts onset of diabetes, particularly in patients with family history.

Aging Insulin resistance has been related progressively to aging, but not all studies relate causation to age alone.

Hypertension Up to 60% of people with essential hypertension have insulin resistance and the metabolic syndrome. A prospective cohort study found that NIDDM was 2.5 times more likely in those with hypertension than in normotensives, possibly due to an intrinsic defect in vasodilatation that decreases efficiency of muscle glucose uptake. Vasodilatory agents such as angiotensin-converting enzyme inhibitors may improve glucose uptake and prevent diabetes.

Inactivity and Obesity Overeating and high-fat diet are the major causes of insulin resistance causing glucose intolerance, the metabolic syndrome, and subsequently overt diabetes. One study using glucose clamps found that obesity may have greater influence

on insulin action than diabetes itself but did not focus on age changes per se. Visceral adipose tissue correlates to insulin resistance in elderly women. A number of large epidemiological studies showed that risk for NIDDM, and presumably insulin resistance, rises as body fat increases from very lean to very obese. This implies that the absolute amount of body fat has an effect on insulin sensitivity across a broad range. Recent studies relate loss of lean body mass to insulin resistance and such changes are common as older people develop frailty and impaired appetite. Increased percent adiposity also contributes.

Human obesity typically arises from increased food intake and decreased expenditure of energy. The surplus energy is stored as fat in adipose tissues. The system controlling fat accumulation involves many different cellular processes, including energy expenditure, digestion, absorption, transport, and storage of nutrient fuels. A complex system of hormonal signaling pathways is coordinated by neural circuits that regulate fat formation. Several hormones produced by adipose tissue play a critical role in the regulation of energy intake, energy expenditure, and lipid and carbohydrate metabolism. For example, leptin is produced exclusively in fat cells and the placenta, and blood-borne leptin signals the brain regarding quantities of stored fat. Leptin receptors in the hypothalamus regulate the neural appetite and satiety centers that control body weight. Although leptin deficiency from a single gene mutation is associated with overweight in homozygous or hemizygous humans, mutations of leptin or its receptor are clinically rare. Rather, it appears that age-related obesity is caused by a spectrum of leptin resistance with hyperleptinemia (analogous to insulin resistance). At present, we are just beginning to unravel the physiology of the complex system that regulates body weight.

Medications Glucocorticoids increase the likelihood of diabetes in susceptible patients. Psychotropic agents, including certain atypical antipsychotics, selective serotonin reuptake inhibitors, and mood stabilizers, have metabolic sequelae, such as obesity, dyslipidemia, glucose dysregulation, and the metabolic syndrome. Case reports, observational studies, retrospective database analyses, and controlled experimental studies suggest that treatment with antipsychotic medications is associated with insulin resistance and weight gain. Persons with schizophrenia and affective disorders also have a high prevalence of risk factors for ischemic cardiovascular disease including diabetes and obesity, that is, 1.5 to 2.0 times higher than in the general population.

Minerals Altered mineral metabolism is prevalent with aging and may affect glucose. Low zinc levels are reported with aging, but for most old people plasma zinc levels are generally normal. However, reliable indicators of tissue zinc nutriture are still being developed, and functional tests suggest that impaired tissue zinc metabolism is widespread and muscle zinc accumulation is altered with aging. Impaired zinc metabolism affects production of essential proteins that may contribute to impaired glucose metabolism. Numerous studies on tissue utilization of zinc have indicated that unusable 'junk' zinc accumulates in aged tissue. Unusable or spent zinc may be bound or chelated to junk proteins in aged cellular tissue. Such junk zinc leads to apparently normal levels despite deficits of useful zinc.

Pathophysiology

Metabolic features of diabetes include impaired carbohydrate metabolism and impaired lipid metabolism. How these change with advanced age is modified by adiposity as well as by declining body weight, which, for men, tends to occur after age 60. Although total body weight may be lower, percent adiposity increases, with a decline in lean mass. While there is a survival advantage to maintaining body weight into advanced age, as indicated by U-shaped survival curves, the implications of the epidemic of obesity-related diabetes will presumably be reflected in accelerated mortality and earlier functional impairment in a subset of the population. New research has strongly suggested that inflammation through activation of the NF kappa beta cascade may be a primary cause of development of age-related diabetes as well as complications including cardiovascular disease.

Carbohydrate Metabolism

Insulin initiates glucose transporter synthesis by binding to the α subunit of the insulin receptor, which phosphorylates the β subunit and activates its tyrosine kinase. Activated kinase signals genes to produce and translocate the insulin-sensitive glucose transporters from an intracellular pool to plasma membranes. Glucose transport and activation of the receptor kinase is impaired with age. Production and translocation of preformed glucose transporters to plasma membranes are also reduced with aging. This leads to impaired glucose transport and accelerated muscle glycogenolysis with age. The common toxic disorder of insulin resistance accelerates aging and may deteriorate to glucose intolerance and diabetes. Skeletal muscle is quantitatively the major site of

age-related impairments responsible for 80–90% of muscle, the tissue responsible for the disposal of 80–90% of an ingested glucose load.

Insulin resistance is manifested by impaired suppression of hepatic glucose output and decreased insulin-stimulated glucose transport and metabolism in adipocytes and skeletal muscle. Hyperglycemia itself by virtue of glucotoxicity can cause insulin resistance, and fasting hyperglycemia is the primary determinant of insulin sensitivity in skeletal muscle.

Impaired insulin secretion increases with age and abnormal first phase insulin release precedes overt diabetes. Some elderly patients develop brittle diabetes with marked insulin deficiency. Recent studies have found that the inflammatory cascade also explains development of age-related insulin deficiency through damage to beta cell function but there remains sufficient insulin that type I diabetic ketoacidosis does not occur.

Lipid Metabolism

Lipids relate to glucose metabolism. Insulin decreases free fatty acids by suppressing lipolysis. Free fatty acids increase hepatic glucose production by stimulating gluconeogenesis. When reduction in free fatty acids during hyperinsulinemic clamp was prevented, insulin-mediated suppression of hepatic glucose output was dampened.

Dyslipidemia with hypertriglyceridemia, low plasma HDL, and small, dense LDL particle concentrations leads to coronary artery disease with insulin resistance and NIDDM. When diabetic control is poor, total cholesterol, LDL, VLDL cholesterol, and triglycerides can be very high and HDL decreased. For men, diabetics do not have rates of abnormal cholesterol different from those of non-diabetics. However, for women, diabetics have nearly double the rate of hypercholesterolemia, and other lipid parameters are worse, increasing cardiovascular risk. The abnormal lipid profile results when insulin augments liver overproduction of VLDL particles with apolipoprotein-B. Insulin and fatty acids mediate transfer of lipids to apolipoprotein-B, thus decreasing apolipoprotein-B degradation. Exchange of VLDL triglyceride for LDL cholesterol esters and subsequent triglyceride hydrolysis yields small dense LDL particles.

Complications

Depression is more common in diabetics than in non-diabetics, and this has been shown to increase the risk of hospitalization.

Macrovascular

NIDDM in the elderly is associated with increased risk of vascular disease. Risk for myocardial infarction is five times higher, and insulin resistance increases death from heart disease. Hypertension and smoking double the risk of cardiovascular disease. Many studies have found an independent association in men and women of increased risk of heart attack and stroke risk that continues into advanced age. For any level of blood pressure, diabetic persons have twice the risk of stroke, myocardial infarction, and peripheral vascular disease. Hypertension and overt diabetes double the risk of cardiovascular disease. In addition, affected individuals have a greater likelihood of having dyslipidemia, hypertension, and obesity. Relative risk for ischemic stroke is 1.8; that for stroke of all types is 3.0. Risk relates to degree of glycemic control, but prognostic association and the magnitude of the effect are less clear in the elderly. Increased risk for hemorrhagic stroke in older diabetic patients is still unsubstantiated but may relate to cardiovascular risk. Silent myocardial infarction increased in men with diabetes, with unrecognized myocardial infarctions three times more common in diabetic than in non-diabetic men; this risk may be greater in older diabetics.

The Framingham Study found that the relative risk for coronary artery disease in diabetic men and women up to age 74 was 2.4 and 5.1 times greater, respectively, than for age-matched non-diabetic men and women. Risk of cardiovascular disease was twice as high for men with diabetes and threefold higher for women, which eliminates the female advantage over men for all outcomes except stroke. In the Islington Diabetes Survey, the prevalence of serious coronary disease increased from 9% in subjects with normal glucose tolerance to 17% in those with impaired glucose tolerance and 20% in those with diabetes.

Macrovascular disease is increased before glucose levels surpass the threshold to diagnose diabetes; 25% of newly diagnosed diabetics have overt cardiovascular disease. Risk of macrovascular disease is increased before glucose levels surpass the threshold at which diabetes is diagnosed. This is reflected by the fact that 25% of newly diagnosed people with diabetes already have overt cardiovascular disease. Women are particularly vulnerable to cardiovascular effects from NIDDM related to menopausal changes.

The Metabolic Syndrome Macrovascular disease is markedly increased by insulin resistance, glucose intolerance, and diabetes. Reactive oxygen species are generated, creating oxidative stress, which exerts major effects on signaling pathways, further affecting

cellular metabolism and triggering low-grade inflammatory reaction. Macrovascular pathophysiology derives from the metabolic syndrome, which leads to a clustering of atherogenic factors. Defects in vasodilatation and alterations in blood flow may provide a link to hypertension in insulin-resistant subjects. The normal vasodilatation response of insulin is disrupted in obese, insulin-resistant, and diabetic individuals, perhaps through inability of insulin to increase endothelial cell nitric oxide. Men with the metabolic syndrome were 2.9–4.2 times more likely to die of coronary disease after adjusting for usual risk factors.

The metabolic syndrome is associated with insulin resistance, but it is not just a consequence of insulin resistance, nor of lack of insulin action. The interface with advanced age has yet to be deciphered. While the metabolic syndrome has become very popular, some suggest that it is time for a re-appraisal because the pathogenesis and clear markers have yet to be defined and some have cast doubt on the value of the metabolic syndrome as a risk marker for cardiovascular disease. New research has suggested that inflammatory markers may explain this process but only limited studies have been performed to date. Insulin resistance alone is not the cause, since patients with insulin receptor mutations or autoimmune insulin receptor antibodies with hundred-fold higher insulin levels are not obese or hypertensive. Some abnormalities of the syndrome actually contribute to insulin resistance, hypertension, dyslipidemia, coronary arteriosclerosis, and stroke. This cluster also causes much of the dysfunction that occurs with usual versus successful aging in the United States.

The metabolic syndrome involves the following markers of inflammation that are closely associated with diabetes, hypertension, and stroke, which may decrease after weight loss:

- Elevated interleukin-6
- Elevated tumor necrosis factor-α
- Impaired fibrinolytic activity
- Easily oxidized, small LDL particles
- Heightened blood-clotting activity
- Increased adipocyte-derived plasminogen activator inhibitor 1
- Increased clotting factors
- Increased fibrinogen
- Increased factor VII
- Increased platelet adhesiveness.

Microvascular

Microvascular complications have been most feared by lay people; this reflects the fact that diabetes is the most common cause of blindness and renal failure in the non-geriatric population. Prevalence of retinopathy was 85% in older diabetic patients, but nonproliferative retinopathy was considerably more common than proliferative. Aging also increases prevalence of renal insufficiency, and correspondingly there is an increased age-related occurrence of diabetes-related renal failure.

Diabetes causes impaired white blood cell function that impedes healing and also prevents wound healing through vascular impairment. Wounds take longer to heal in part due to the immune compromise that is caused by diabetes, notably interference with white blood cell chemotaxis and leukocyte killing capacity.

Neurodegenerative

It has long been recognized that older patients with diabetes develop some cognitive impairment, but recent studies have found that incidence of Alzheimer's disease is higher in those with diabetes. There is growing evidence that the spectrum of insulin resistance and NIDDM glucose intolerance plays a major role in common neurodegenerative disease. Incidence of dementia will increase 400% in the next 20 years. Neurodegenerative disease is predicted to replace heart disease as the largest cause of death and disability among elderly people during the first century of this third millennium. Impaired glucose metabolism may contribute to the two major causes of dementing illness, multi-infarct dementia and Alzheimer's disease, which make up 80% of all dementia. Weight loss from decreased appetite may occur during the subclinical phase or initial onset of dementia, which explains lack of association with weight changes near the time of diagnosing dementia. In a retrospective study of 10 276 men and women in their 40s, compared with those of normal weight, those with body mass index greater than 30 had 74% higher risk of dementia, while those with body mass index greater than 25 had 35% greater risk. A prospective study found obesity in elderly woman increased the risk of dementia.

NIDDM prevalence is significantly higher among those with Alzheimer's disease. Increased CNS amyloid relates directly to development and progression of Alzheimer's disease, and insulin-degrading enzyme has a role in degrading amyloid β-protein. Lower levels of this enzyme relate to degree of insulin resistance. Deficient insulin signaling with decreased PI-3 kinase correlates with reduced insulin-degrading enzyme in Alzheimer's brains. No prognostic studies have investigated potential therapy. Cardiovascular disease and diabetes also increase dementia associated with interleukin 6 and C-reactive protein.

Atypical presentation in elderly diabetics includes the following:

- hyperosmolar non-ketotic coma
- malignant external otitis
- emphysematous cholecystitis
- neuropathic cachexic, especially in older men.

Treatment and Prevention

Diabetes in all adults, particularly in older adults, is altogether a patient's illness since compliance has the largest impact on the course of the disease. What appears more relevant is that diabetes, or at least the bulk of the cases that are diagnosed in adults, is entirely preventable by lifestyle modifications. Compliance for such recommendations is no easier now than it was for Catoni. Very few behavioral therapists and some lifestyle-oriented workshops or clinics are successful in getting patients to comply. Those patients most interested in making lifestyle changes are often those who recognize the impact of their behavior on their sexual function. A broader solution for this epidemic awaits societal shifts, health conscious motivation, or more effective medication.

What seems particularly compelling about this clinical predicament is that arteriosclerotic disease may well be preventable and possibly reversible by simple non-toxic maneuvers. Such conceptions were broached by the paradigms of usual aging as opposed to successful aging developed in the 1980s. Certainly in terms of diabetes and the metabolic syndrome, lifestyle choices affect much of the resultant age-related disease, and clinicians have been less motivated to encourage changes. These simple issues become increasingly relevant with the shift in prevalence of diabetes across the world. Some patients are sufficiently insulin deficient that diet and exercise are not as helpful even though insulin deficiency promotes development of insulin resitance.

Diet

Caloric restriction improves whole body glucose homeostasis, increasing insulin sensitivity even though obesity is not controlled, and is advocated as a first-line therapy. Caloric restriction studies show slowing in many aspects of age-related deterioration in rodents, including glucose tolerance, despite finding very high levels of stress hormones, including glucocorticoids. Thus, caloric restriction sufficient to maintain a negative energy balance with or without exercise is highly desirable for diabetes control by reducing hepatic glucose production, fasting hyperinsulinemia, lipid profile, glucose tolerance, and blood pressure, and can possibly prevent diabetes. People at risk of NIDDM decreased that risk by more than half by exercising moderately only 30 min/day, losing only 5–10% of their body weight. During one study of people over 60, risk was cut by 71%. One possible mechanism for improvements in insulin sensitivity through weight loss may be effects on the pattern of muscle fatty acid metabolism and the accumulation of lipid within muscle. Response to such dietary therapy for diabetics of advanced age may reflect differences in pathophysiology because of age-related decrease in appetite and body weight. Controlled diet therapy studies have yet to be completed for the oldest-old and for nursing home patients since some suspect that this will not be helpful, as such patients have lost enough weight with advanced age.

Specific food types impact glycemia. The amount of fiber eaten affects glycemic response to meals. There are large differences in different starch-containing foods. Cooking starch-containing food increases glucose by half. Raw starch ingestion led to 44% less glucose response and 35–65% less insulin response compared to eating glucose or sucrose. Foods such as rice and potatoes release more glucose in relation to time of cooking, but uncooked legumes, which have more indigestible starch, are ideal foods to control diabetes. Patients who ate whole grains in a long-term cohort study had less risk of NIDDM compared to controls who ate white rice. Such studies suggest that eating a raw vegetable calorie-restricted diet would decrease incidence and delay development of diabetes. A previous study also found that compared with a diet of 45% fat, 40% carbohydrate, 1 and 15% protein, a higher carbohydrate diet of 30% fat, 55% carbohydrate, and 15% protein increased fasting triglycerides by 41%. Postprandial triglyceride, glucose, and insulin levels were also higher on the higher carbohydrate diet, and triglycerides relate to cardiac risk for diabetics. Another study of a 60% carbohydrate diet compared to a diet with less carbohydrate but more fat found for patients on the 60% carbohydrate diet glucose and insulin concentrations significantly elevated throughout the day, doubled 24-h urinary glucose excretion, and 30% higher total and VLDL triglyceride with lower HDL. Fatty foods may be more likely to induce obesity. When converting ingested fat to fatty acids and then esterifying these to triglyceride for fuel storage in adipocytes, only 3% of the net fuel consumed as food is lost, but for ingested carbohydrates, 10 to 15% of the energy is lost. Hence, eating fatty food may increase the amount of weight gained.

Exercise

Glucose utilization for healthy elderly relates closely to fitness as measured by maximal aerobic capacity, but evidence varies as to whether exercise improves diabetic control in older diabetics. Four months of aerobic exercise can improve muscle oxidative capacity similarly in young and old, but insulin sensitivity is less likely to improve in older people and benefits take longer and require more frequent training. Others found that exercise may reverse the metabolic syndrome for some elderly hypertensives, improves insulin resistance without weight change, reduces cardiovascular disease, and may decrease total mortality as much as 44%. However, it appears that benefits from exercise are transient and may disappear shortly after stopping. Effects of exercise on insulin sensitivity have been proposed to be due to number of glucose transporters, changes in capillary density, and increases in the number of red glycolytic fibers. Age effects are unclear. Increasing lean body mass by resistance exercise may also improve glycemia especially among frail diabetics.

Glycemic Agents

Copper, magnesium, and chromium were implicated with some benefits, but supplementation does not improve glucose tolerance in old people. Lithium and vanadium help, but toxicity occurs near therapeutic doses. However, toxicities of zinc appear to be the least, and zinc has broadest involvement in normal metabolic processes, with more than 300 known zinc-requiring proteins and enzymes. Zinc activates insulin receptor β subunit autophosphorylation to stimulate glucose uptake in insulin-requiring cells at sites that deteriorate with age. Glucose intolerance and insulin resistance occur with zinc deficiency. Supplementary zinc may help impaired glucose tolerance, but results have not been consistently replicated. In contrast, zinc added to prostate extract, to the prostaglandin precursor arachadonic acid, or to the pancreatic peptide cyclo-histidine-proline, did improve glycemia in multiple experiments. Discrepancies may derive from inadequate tissue zinc utilization. Experiments have indicated that pancreatic cyclo-histidine-proline acts like an oral form of insulin and enhanced muscle zinc utilization. This peptide also reverses insulin resistance in aged rodents as documented by euglycemic clamp studies. At higher doses the peptide appears to decrease leptin resistance, with food intake decreasing up to 45% in aged obese rats. Sustained 10% weight loss has been observed. There was no significant change in food intake when young non-obese rats were given the same treatment, and no toxicities have been observed.

Analogous results with metformin include less improvement acting predominantly by decreased appetite and hepatic glucose production not enhanced by muscle glucose utilization. Metformin was recently used in a trial to prevent development of NIDDM in glucose-intolerant patients, but that study was not geared toward old people. Troglitazone improves muscle insulin action, but fatalities occurred and the drug was taken off the market. The safety and utility of rosyglitazone are not yet confirmed for the aged. The same therapeutic dearth pertains to glucose intolerance due to age or obesity. There is concern with using metformin and glitazones because of potential age, renal, and cardiac-related toxicities. Insulin-augmenting agents such as repaglinide, designed to normalize postprandial glucose excursions, increase early and late phases of insulin responses in hyperglycemic patients without markedly enhancing insulin secretion in euglycemics and are less hypoglycemia-prone than sulfonylureas and have limited indications.

Vascular Treatment

Increased risk of heart disease in patients with diabetes has prompted the recommendation that individuals with diabetes be treated for their dyslipidemia as aggressively as individuals who have had a previous myocardial infarction. In addition, individuals with the metabolic syndrome are in a higher risk category and should also be aggressively treated to lower lipids. LDL level is not as valuable as the LDL/HDL ratio. Most coronary prevention measures, including weight control, exercise, avoidance of cigarettes, and improvement of glucose tolerance, also increase HDL.

Intensive Glycemic Control

The UK Prospective Diabetes Study evaluated tight insulin control for NIDDM. After 10 years, glycemia significantly improved, with 25% reduced retinopathy and nephropathy. Intensive therapy decreased development and slowed progression of diabetic neuropathy. Four weeks of intensive glycemic therapy improved glycemic nerve conduction velocities, increased strength-duration time constant, and decreased rheobase. The lack of focused outcome studies for the elderly suggests that the benefit of tight glycemic control to prevent or treat neuropathy, nephropathy, and retinopathy is unclear in elderly diabetics. This may in part relate to the duration of disease and the time course of benefits in relation to survival of older patients.

Potential Reasons for Tight Control in Older Diabetics

Clinical trials have demonstrated lower risk of developing or progressing retinopathy, nephropathy, or neuropathy. Follow-up studies have shown that previous degree and duration of glycemia are important risk determinants for microvascular complications. This prevents and improves retinopathy, but such issues are not well studied in certain elderly groups even though a very high percentage of older diabetics (>80%) have background retinopathy. Progressively lower risk to develop acute myocardial infarction is seen with improved glycemia. Data on macrovascular risk benefit for elderly is inconclusive, but a study of 229 65- to 75-year-old subjects found linear association of glycemic control with 3.5 year coronary mortality. A few years of good glycemic control may reduce the risk for cardiovascular events a few years later, but the role of tight glycemic control in reducing the risk of stroke is still uncertain. Previous studies extrapolated such results to older patients, but no evidence-based studies of tight control have focused on elderly patients.

Reasons why improved glycemic control may be beneficial for older diabetics include the following:

- Improved urinary incontinence
- Better glycosuria with improved inanition, better fluid balance
- Improved energy level, fatigue; possibly better mood
- Improved white cell chemotaxis; possibly improved wound healing
- Improved nerve conduction; possibly better neuropathic symptoms
- 50% better mortality for ICU patients, acute myocardial infarction, and acute stroke
- Improved glucotoxicity, better insulin release, better insulin action, not studied in elderly.

Potential reasons why tight control may not be a good idea for older diabetics include the following:

- Limited evidence-based trials on prevention and treatment of microvascular complications in specified elderly populations; especially understudied in nursing home patients
- More patients have visual problems interfering with complex treatments or insulin adjustments
- Less neuronal reserve should patients suffer hypoglycemia
- Cardiac impact of hypoglycemia is more likely in older diabetics and may worsen angina
- Elderly are more likely to have renal impairment and decreased drug clearance
- Impaired dawn phenomenon with aging; less capacity for counter-regulatory response
- Diminished tissue sensitivity to β-adrenergic signals
- Less likely to get warning symptoms if glucose falls and have impaired vasoreceptor response
- Older men are prone to more severe cognitive impairment during hypoglycemia
- Toxicities are more likely for metformin and are unclear for glitazones
- Tight control is poorly studied in the oldest-old, notably nursing home patients
- Altered renal, hepatic function, polypharmacy, complex regimens increase toxic risk
- Decreased clearance of insulin
- More liable to develop hypoglycemia; decreased clearance of oral medication, notably sulfonylureas with potential for protracted hypoglycemia.

It appears that optimal therapy for older patients with diabetes is best guided by two considerations, the likely duration of survival in terms of time to worsened complications and likelihood that hypoglycemic risks may outweigh potential benefits. In one study of patients older than 65, many hypoglycemic events occurred and more than one-third of these were severe. Patients of advanced age have large interindividual differences. Some are particularly frail while others may be relatively active, and as a result life expectancy varies tremendously for the oldest-old or nursing home patients. It is difficult to manage risk of hypoglycemia in frail patients. Studies in ICU patients may be a model for the frail elderly, but this is not yet clear. Non-glycemic therapy may be most germane. Short-term trials do show benefit for retinopathy and nephropathy from blood pressure control. For any level of blood pressure, diabetic persons have a doubled risk of coronary disease, stroke, or peripheral arterial disease.

See also: Cardiovascular System; Dementia; Diet and Nutrition; Exercise and Physical Activity; Metabolism: Carbohydrate, Lipid and Protein; Obesity; Stroke.

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Diet and Nutrition

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Glossary

Anorexia – A lack of appetite leading to low food intake.

Body Mass Index (BMI = kg/m^2) – A ratio of weight (kg) over height (m) that is commonly used as a measure of overweight.

Endogenous Opioid – A naturally occurring peptide with effects similar to morphine.

Preload – A fixed amount of food given before a meal in order to test how well people adjust or compensate for the calories or nutrients in the preload.

Primary Aging – Changes in physiological or metabolic functioning that are due primarily to age.

Satiety – The reduction of hunger and the termination of eating that mark the end of a meal.

Secondary Aging – Effects due to acute and chronic disease and medication use.

Sensory-Specific Satiety – As a food is eaten it is judged as less pleasant, whereas the pleasantness of other foods is unchanged.

Introduction

Aging is accompanied by a variety of physiological, behavioral, and socioeconomic changes that may have a negative impact on diet and nutritional status. Energy needs and energy intake decline with age, as do body weight and lean body mass. Poor health, the use of medications, and sedentary lifestyle may all contribute to age-related anorexia and inadequate dietary intakes. Nutrition studies conducted in clinical and in community settings have pointed to an increased risk of nutrient deficiencies among the elderly. Diets of the elderly have also been described as monotonous and bland, and are said to be marked by sharply reduced consumption of nutrient-dense foods.

Although the prevalence of malnutrition among the elderly in the United States is reported as low, aging does place individuals at greater nutritional risk. There are many ways in which the aging process can influence diet and nutrition (see **Table 1**). First, primary aging has been associated with altered sensations of hunger, thirst, and satiety and with imperfect compensation for day-to-day variations in the diet. Low fluid intake, for example, is not compensated for by increased thirst. Sensory-specific satiety, which may serve as a variety-seeking mechanism, is also reported to be reduced. Age-related deficits in smell, and possibly taste, may lead to a lowered enjoyment of foods. These age-related physiological changes may account, in part, for the reported poor quality of the diet in older individuals.

Secondary aging is defined as including some of the age-associated chronic disease states, notably

Table 1 Influences on the nutritional status of the elderly

Primary aging
Changes in the regulation of thirst and fluid intake
Changes in the regulation of hunger and food intake
Poor compensation for the energy content of foods
Changes in satiety possibly related to hormones, neurotransmitters, or gastrointestinal tract
Decreased energy output
Lowered physical activity
Slowed metabolic rate
Alterations in ability to taste or smell
Alterations in sensory-specific satiety
Secondary aging
Chronic disease states
Cardiovascular (e.g., hypertension, atherosclerosis)
Endocrine (e.g., hyperlipidemia, diabetes)
Cancer
Infections
Gastrointestinal (e.g., constipation, diarrhea, nausea, malabsorption)
Swallowing problems
Pulmonary
Muscular and neurological (e.g., stroke, immobility)
Psychiatric (e.g., depression, dementia, anorexia nervosa)
Medications
Medically prescribed diets
Poor oral health and dentures
Socioeconomic influences
Lower economic status
Retirement
Failing health
Fixed income
Death of spouse
Social isolation and loneliness
Bereavement

hypertension, hyperlipidemia, atherosclerosis, and diabetes. The presence of chronic disease together with the use of medications and medically prescribed diets is likely to have an impact on energy intake and on diet choices. Impaired mobility, inability to feed oneself, poor oral health, or the use of dentures can also affect the amount and types of foods consumed. In addition, nutrient malabsorption can be caused by altered gastric acid secretion or by interaction with medications.

Finally, social and economic factors play a vitally important role. Old age has been associated with lower economic status that may stem from retirement, failing health, living on fixed income, or death of a spouse. Social isolation has been associated with depression and loneliness, which in turn can be linked to significant changes in eating patterns. These factors can influence the type and quality of food consumed. Marital status, for example, has a major impact on the diets of elderly men, and it is generally accepted that socialization at meals can increase energy intakes.

Primary aging, disease states, and social factors can all affect diet and nutrition in the elderly. Describing their respective contributions is the primary focus of this article.

The Population at Risk

The elderly are the fastest growing segment in the US population. Over 25 million Americans are over the age of 65. By the year 2030, 57 million people are expected to be 65 years or older. Yet the elderly are not a homogeneous population with uniform nutritional needs. Although some subgroups may be at greater risk for anorexia and associated nutritional deficiencies, others, especially women, are more likely to be overweight and obese. In general, body weight increases until late middle age, then plateaus and decreases for older persons.

Nutritional surveys of the US population have shown poor correlations between reported dietary intake of nutrients and clinical and biochemical measures of nutritional status. For example, data showing inadequate intake of energy and protein among the elderly are difficult to reconcile with increased prevalence of obesity and increased percentage of body fat. However, many measures of dietary and nutritional assessment may not be applicable to older people. Most of the nutritional standards that have been used were generated from data on young individuals and were then extrapolated to the elderly. Awareness of the problems this can cause is leading to collection of more data on intake patterns of the elderly. However, the assessment of dietary intake in large-scale epidemiological studies is often based on self-administered food frequency questionnaires or diet records. Such procedures place demands on memory and cognition and their accuracy may be compromised by forgetfulness, fatigue, or dementia. Dietary intake assessments that are shorter and interview based may be more appropriate for use with the elderly populations. The accuracy of body composition measures also changes as a function of age. Although body fat in young people is stored largely in subcutaneous depots and can be easily measured by skinfold thickness, much of the body fat in older people is stored in the trunk, which is harder to measure using readily accessible techniques such as skinfold thickness. These various assessment problems make it difficult to draw firm conclusions about the nutritional status of the elderly, especially because they are a heterogeneous group. One thing is clear: there is a need for two sets of age-specific nutritional status standards for older people, one set for the free-living

population and one for those who are chronically or acutely ill.

With these problems in mind, we will briefly examine what existing nutritional surveys indicate about changes in body weight (BW) and nutritional status with age. The National Health and Nutrition Examination Survey II (NHANES II, 1976–80) shows that the prevalence of overweight increased with age. As shown in **Figure 1**, older people weigh more and many are fatter than are young people. Body mass index (BMI), the principal measure of overweight for adults, is correlated reasonably well with body fatness.

In contrast to BMI, energy intakes decline as a function of age. Based on a single 24-h diet recall, a more recent NHANES III study (NHANES III phase 1; 1988–91) (see **Figure 2**) shows that median energy intakes for adults aged 70–79 years are 1797 kcal for men and 1382 kcal for women. The reported macronutrient composition of energy in their diet is approximately 50% carbohydrate, 16% protein, and 34% fat. These data are similar to the results reported for the population as a whole. However, the finding that intake of some vitamins and minerals is low has given rise to concerns that some elderly individuals may consume inadequate levels of nutrient-dense foods. For example, low consumption of calcium and vitamin D has been attributed to low intake of dairy products by the elderly.

Anorexia, or low food intake, is a problem in the elderly because it increases the risk of nutrition-related illness. Though nutritional surveys have shown a low-to-moderate prevalence of nutrient deficiencies in free-living populations, elderly persons

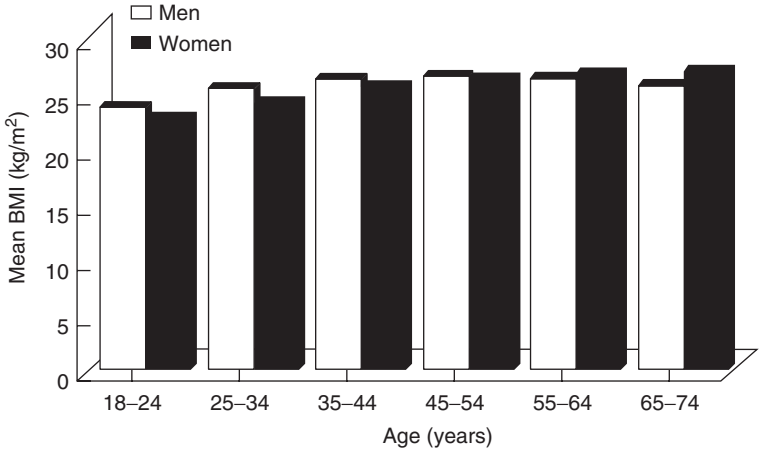

Figure 1 Body mass indices (BMI) for US men and women by age from the National Health and Nutrition Examination Survey II, 1976–1980 (NHANES II).

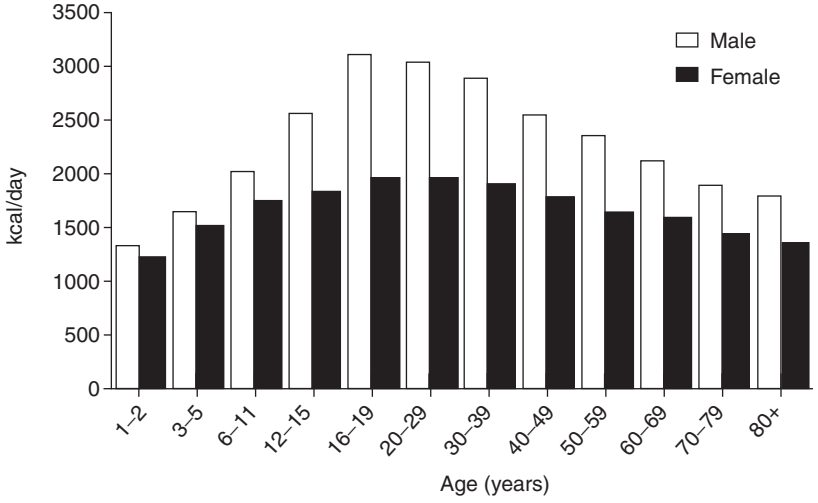

Figure 2 Energy intakes (kcal) for men and women by age from the National Health and Nutrition Examination Survey III, 1988–1991 (NHANES III).

living in institutional settings may be at greater risk for malnutrition. Although estimates vary, between 30 and 60% of long-term care older institutionalized individuals have some degree of malnutrition. Studies show that poor nutrition and low BW are not simply a result of disease states, but often precede and predispose elderly individuals to disease and death.

Loss of appetite can be caused by age-related psychological and physical factors. Eating patterns can be influenced by mental factors, such as depression or dementia, and physical factors, including immobility, inability to feed oneself, and poor dentition or ill-fitting dentures. Many elderly individuals have problems with their oral cavity. For example, 42% of the geriatric population in the United States have no natural teeth. Of those with their teeth, 60% have tooth decay and 90% have gum disease, which impair their ability to chew. Tooth loss also affects chewing ability, and this is not completely restored by dentures. Impaired chewing can cause changes in food selection, such as decreasing the variety in the diet, which could contribute to nutritional problems.

Decreased physical activity and a slower metabolic rate are part of the explanation for lowered food intake in the elderly. However, decreased energy demands cannot be the explanation for why nutritional problems related to low food intake develop.

Thirst and Fluid Intake

Studies on the regulation of fluid intake demonstrate the difficulty experienced by many elderly persons in adjusting to environmental changes and in maintaining their internal state. Salt and water imbalances can lead to illness and death. These difficulties are partly caused by age-associated changes in regulatory systems. Maintenance of sodium and water homeostasis depends on a balance between intake, controlled by thirst and sodium appetite, and output, controlled by the kidneys. Thirst and water intake play a vital role in maintaining fluid and electrolyte balance, because it is only through these intakes that water deficits can be replenished. Conservation of water by the kidneys can only minimize further losses.

Although dehydration is a common cause of fluid and electrolyte disturbance in the elderly, it is a common clinical observation that the elderly do not seem to get thirsty despite obvious physiological need. Clinical studies have examined the effects of dehydration on thirst in both healthy young and healthy active elderly men. The men were dehydrated by depriving them of water and were asked to consume a dry diet. After 24 h without fluids, the elderly men had a reduced ability to experience the sensation of thirst, and they did not drink adequate amounts of water to restore fluid balance. Additional studies have shown that the elderly do not restore fluid losses induced either by exercise or thermal dehydration. The impaired thirst in elderly individuals is due, in part, to changes in the receptors in the central nervous system (CNS) that detect changes in the level of sodium in blood (*see* Thirst and Hydration).

The Regulation of Food Intake

Several recent investigations have tested the hypothesis that, analogous to the situation for the regulation of fluid intake, aging is associated with a decline in the regulatory mechanisms that influence hunger, appetite, and food intake.

One study demonstrated that elderly men do not adjust their food intake following periods of over- or underfeeding. During a period of *ad libitum* intake following 21 days of overfeeding, younger men (mean age 24) lost the excess weight gained during overfeeding, whereas the older men (mean age 70) did not. A similar indication of impaired regulatory ability was seen following 21 days of underfeeding in that younger men (mean age 22) regained lost weight and older men (mean age 66) did not. Measurements showed that energy expenditure was unaffected by aging, whereas food intake was not adjusted appropriately to compensate for the over- or underfeeding. Although this study shows that the ability to adjust food intake in relation to BW is impaired in older men, it does not touch on whether aging is associated with changes in hunger and satiety or whether the elderly can adjust appropriately to changes in the energy content of foods.

The preloading method has been shown to be a sensitive test of the regulatory capabilities of young study participants. When fixed amounts of a food (preloads) varying in energy content are given 30 min before lunch, the degree to which intake at lunch is adjusted for the energy in the preloads indicates how well food intake regulatory mechanisms are functioning. Thus, healthy elderly (ages 60–84) and young (ages 18–35) men were given either yogurt preloads that varied in energy content or no yogurt followed by lunch. The elderly males consumed significantly less energy at lunch than the young males in the baseline (no yogurt) condition. Lower intake was concordant with subjective sensations of satiety; ratings of subjective sensations indicated that the older men were less hungry and more full at the start of lunch. This could be part of the explanation for lower intake. The elderly men also showed an impairment in energy intake regulation. Compensation for energy in the

preloads was less precise in the elderly than in young males; older men did not appropriately reduce intake at lunch to compensate for the calories in the yogurt.

There are changes in a number of physiological and metabolic systems with age, but the link between these and changes in the regulation of food intake has not been established in humans. Animal studies point to physiological changes that could be involved in changes in food intake regulation with age. For example, it has been shown in young animals that some naturally occurring peptides such as endogenous opioids may be involved in determining the palatability of food and in initiating and terminating eating. Studies indicate that older rats show diminished responses to blockade or stimulation of opioid peptides compared to young rats. Also, older rats have a lower concentration of endogenous opioid peptides in some areas of the brain.

Changes in the gastrointestinal tract with age may affect food intake. The presence of food in the stomach and gut can affect food intake through receptors that detect stretch, or the concentration of nutrients or electrolytes such as sodium. The early onset of satiety sometimes experienced by the elderly could be due to alterations in the hormonal responses that normally accompany eating. For example, cholecystokinin (CCK), a hormone released by the gut in response to eating, has been shown to decrease food intake. Studies in mice show that CCK decreases food intake more in older than in younger animals. CCK also has a prolonged action in older mice. CCK levels have been found to be elevated in older humans. This, combined with an increased sensitivity to CCK, could lead to early satiety in the elderly. Another factor that could affect satiety is the rate at which foods and drinks empty from the stomach. The emptying of solid and liquid foods has been found to be significantly slower in older subjects. Although the difference in stomach emptying is small, it is possible that retaining food in the stomach could affect hunger and satiety and the pattern of meals; that is, the interval between meals might be expected to be longer. This needs to be assessed experimentally by recording food intake (*see* Gastrointestinal System: Function and Dysfunction).

A number of other possibilities have been suggested to explain the anorexia of the elderly, such as changes in various neurotransmitters and hormones. However, there is no direct evidence to support such speculation. Indeed none of the physiological changes associated with aging have been directly linked to changes in food intake regulation in elderly humans. Clearly, more studies are required to understand changes in physiological systems that impact on the nutritional status of the elderly.

Deficits of Taste and Smell

It is commonly believed that age-related deficits in taste and smell are directly responsible for some of the nutritional problems in old age. However, there is very little direct evidence to link diminished sensory functioning with inadequate nutrition and ill health. While there is general agreement that many elderly people suffer from deficits in smell, and possibly taste, the impact of such impairments on nutrition and diet has not always been clear. No study has demonstrated a causal relationship between sensory deficits and altered food choices in the elderly, and there is little evidence to link chemosensory deficits with nutritional status.

There is no doubt that sensory impairments do occur. Studies on taste sensitivity have observed some decline of taste acuity with age, especially after the age of 70 years. Taste sensitivity to water solutions of sweet, sour, salty, and bitter compounds was measured using detection and recognition thresholds. The detection threshold was the minimum concentration of a solution that was perceived as distinct from distilled water, whereas the recognition threshold was the level at which the solution was perceived as salty or sweet. Taste sensitivity was also assessed at solution concentrations above threshold. Studies showed an increase in detection and recognition threshold levels among the elderly and, in some cases, impaired perception of more intense solutions, notably those with bitter and sour tastes.

Although the loss of taste sensitivity with increasing age was initially attributed to degeneration and loss of taste buds, it now appears that the taste system is relatively robust, and that whole-mouth tasting is stable even in late old age. On the other hand, localized taste losses do occur in some elderly subjects, although sometimes they go unnoticed. Taste losses that have been observed among the elderly may be the result of cumulative pathology, including poor oral health, rather than the inevitable outcome of primary or normal aging.

Despite reports of diminished taste acuity for dilute solutions, the perception of sweet, sour, salty, and bitter tastes in foods appears to be resistant to age. Sensory evaluation studies have failed to observe age-related deficits in ratings of saltiness in tomato juice, or a decline in the perception of saltiness in potatoes or broth, or sourness in apple drink. There was no age-related deficit in the intensity ratings for salt and sugar in salted or sweetened dairy products. Only one study reported an age-associated decline in the perception of protein taste in soup.

However, conventional studies on taste acuity do not give an indication of how aging may affect taste

preferences. Arguably, not taste perceptions but taste preferences are likely to affect food preferences or food dislikes. Taste preferences have been measured by asking subjects to rate the perceived pleasantness of a stimulus, or through direct ratings of like and dislike. However, hedonic ratings can be influenced by the type of the stimulus, or by the subjects' own concerns with health and dieting. As a result, studies on taste preferences of older subjects have produced no consistent pattern of results. Whereas one early study reported that older subjects preferred less sweet samples of pineapple juice, some later studies showed that the elderly, on the contrary, preferred sweeter and saltier stimuli than did younger subjects. One study reported an increase in liking for higher concentrations of salt with age, but only for water solution and not for chicken soup. Other studies reported no difference in hedonic preferences for sweet solutions between children, young adults, and the oldest adults.

Only one study showed a clear increase in preferences for more intense solutions of sodium chloride, sucrose, and citric acid as a function of age. Four concentrations of each stimulus were presented either in water or in vegetable juice or lemonade. In general, the subjects judged beverages as more pleasant than water solutions. Older subjects preferred higher concentrations of sugar and salt in both water and beverages than did younger subjects. This shift in hedonic preferences toward higher levels of sugar and salt was again thought to be caused by age-related impairments in sensory function.

Though it is generally believed that elevated preferences for salt taste are associated with increased sodium intakes, no study so far has managed to link sensory preferences for salt to dietary sodium intakes at any age. Measures of salt taste preference in the elderly have not been linked to estimated salt intakes. Similarly, no study has linked altered preferences for sweet taste with changes in sugar consumption in the same subject population.

The taste impairments observed in several studies might be the consequence of poor health, including poor oral health, or medication use, and not a direct consequence of normal aging. Whatever the reason, no study has shown a causal link between such impairments and altered patterns of food intake or inadequate nutrition. Research attention has therefore focused on aging and the sense of smell.

The perception and identification of odors is clearly impaired in the elderly. The University of Pennsylvania Smell Identification Test (UPSIT), composed of 40 odors on paper strips, has been used to assess smell functioning in a large number of people including the elderly. In one study, the subjects were 1955 men and women aged 5 to 99 years, including university students and employees, residents of homes for the elderly, and primary and secondary grade school students. Odor identification data (**Figure 3**) showed that women were better than

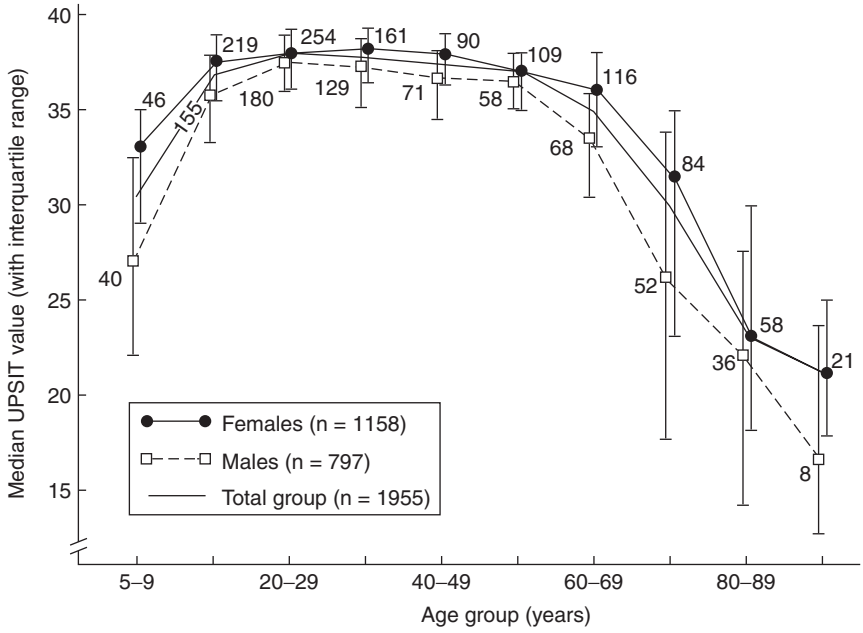

Figure 3 University of Pennsylvania Smell Identification Test (UPSIT) median scores as a function of age and gender. Reproduced with permission from Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, and Rosenberg L (1984) Smell identification ability: changes with age. *Science* 226: 1441–1443. Copyright 1984 American Association for the Advancement of Science.

men and non-smokers were better than smokers. Peak performance was seen among subjects aged 20–40 years, with a sharp decline observed after age 60 years. More than half of the people aged 65–80 years had a major olfactory impairment, while three-quarters showed olfactory impairments after the age of 80 years.

Arguably, the selection of real-life foods involves smell rather than taste. Identifying and distinguishing between foods depends on the perception of taste, flavor, and texture. Studies on sensory identification of foods by the elderly showed that food recognition diminished with age. In a pioneering study, young college students (ages 18–22) and elderly residents of a retirement home (ages 67–93) were presented with 24 different foods to taste and smell. Fresh fruits, vegetables, meats, fish, nuts, grains, and dairy products were steamed, blended and strained, or pureed. Water was added to minimize texture differences. Blindfolded subjects were first presented with a container of food to smell, and then they tasted a teaspoon of the food sample.

The results showed that elderly subjects were sometimes unable to identify blended foods by taste and smell. Out of 24 foods, 21 were more frequently identified by young people than by the elderly. More elderly subjects than younger ones commented on the weakness of taste and smell for the unseasoned, blended foods.

Impaired food identification by the elderly is therefore more likely to involve smell rather than taste deficits. In another study, young (ages 18–26) and older people (ages 65 years and over) attempted to identify pureed foods while blindfolded, using only taste and odor cues. The freshly prepared, steamed, and blended foods were potato, tomato, carrot, broccoli, celery, lemon, pear, banana, beef, coffee, sugar, and salt. Younger people identified more foods on the first attempt than did older subjects. Repeating the task with nostrils pinched to eliminate olfactory input removed the age-related differences, suggesting that the foods were identified largely by smell. The key question is whether impairments of smell in the elderly have a measurable impact on food selection.

There is evidence that sensory factors related to the sense of smell play an important role in diet choice. The elderly rated taste, or specifically flavor perception, as a strong influence on their food choices. In a recent survey, 30 elderly individuals ranked the factors that affected their food purchase decisions in three different eating situations (celebration, eating with a friend or spouse, or eating alone). Familiarity and prior experience with foods and the sensory properties were significantly more important than other factors in all three situations, except when eating alone, when ease of preparation was the most important. Apparently the elderly were often unaware of their sensory loss and reported no decrease in their appreciation of foods or in their ability to smell. It may be that when sensory losses occur gradually over a period of years, the importance of smell in promoting appetite also gradually declines and cognitive compensatory mechanisms take over. In a recent study, smell deficits were observed in a large proportion of elderly women. However, their impact on food consumption patterns and nutritional status appeared minimal.

Still some scientists believe that sensory impairments are the direct cause of reduced pleasure response to foods that may result in a consumption of a monotonous and nutritionally inadequate diet. One intervention approach has been to restore the missing sensation by adding synthetic flavorants to food. These studies reported that flavor amplification increases the intake of nutrient-dense foods in the elderly and may result in improved nutritional as well as immune status (*see* Smell and Taste).

Dietary Variety and Food Selection

Age-related sensory impairments are said to result in the consumption of a more monotonous diet. Some studies have reported a decline in dietary variety with age. Analysis of the self-reported dietary intakes of elderly participants in the 1977–78 National Food Consumption Survey (NFCS) showed that the oldest participants consumed the least varied diets. These data were based on a sample of adults more than 54 years old ($n = 4983$) drawn from among more than 30 000 people interviewed in the NFCS study. Food consumption data were based on one 24-h food recall and 2-day food records.

Consumption patterns were analyzed using two separate measures of dietary variety. The first measure, the variety index, was calculated by counting the number of different foods in each of 18 previously defined food groups that were eaten by each individual over 3 days. The elderly respondents ate approximately 35 different foods over 3 days, with men reporting more different foods than did women. The variety index declined slightly from the youngest (age 55–64 years) to the oldest group (>75 years).

The second measure, that of core foods, was based on a straight frequency tally of foods consumed over the 3-day period. Foods consumed on at least one of the 3 days by approximately 50% of the elderly respondents were whole milk, coffee, white bread, potatoes (other than fried), margarine, and sugar. The authors noted that these items were relatively

inexpensive, simple to chew, and easy to prepare. They also noted that a higher proportion of the sample population 75 years and above lived alone and had lower income and educational levels.

An analysis of the most frequently consumed foods in the NHANES II database shows that coffee, white bread, and margarine are the core foods of the American diet. These foods were consumed by more than 50% of the respondents on any given day. The most frequently consumed foods were coffee and tea, white bread, margarine, whole milk, doughnuts, cookies and cake, and sugar. The core foods of the elderly and the core foods of the general public are in fact very similar. Moreover, nutritional trends among the elderly have followed those of the American public. A comparison of 1977–78 NFCS data with the 1985 Continuing Survey of Food Intakes by Individuals showed that American women ages 19–50 years reduced the consumption of red meat and full-fat milk, but consumed more low-fat milk and low-calorie soft drinks. A similar analysis of intake trends for the elderly showed that they too reduced the consumption of meat, and increased the consumption of low-fat milk, low-calorie beverages, and take-out foods.

The moderate trend toward consumption of a less varied diet seen in community-dwelling elderly individuals is much more pronounced in long-term care facilities. A survey of 303 institutionalized persons over 65 found that almost two-thirds had changed their diets within the past 5 years. Many of these changes resulted in subjects eating less or restricting their food choices. The effect of limited food choice on the health and nutritional status of the elderly can be serious because consumption of a varied diet is considered the most effective way to assure adequate nutrient intake.

One possible explanation for reduced dietary variety involves altered pleasure responses to food. Normally, as foods are consumed they become less pleasant. This decline, called sensory-specific satiety, is associated with a shift to other food choices during the meal. As a result, people eat more foods when offered a variety of choices than when a single food item is available. Sensory-specific satiety can therefore promote the intake of a more varied and nutritionally balanced diet.

Because sensory-specific satiety encourages consumption of a varied diet and because the elderly have relatively monotonous diets, a reasonable hypothesis is that the elderly have diminished sensory-specific satiety. The effects of age on sensory-specific satiety were investigated in adolescents (ages 12–15), young adults (ages 22–35), older adults (ages 45–60), and the elderly (ages 65–82). Subjects rated the pleasantness of the sensory properties and their desire to eat five foods and then ate either a fixed amount or as much as they wanted of one of the foods (yogurt). They rerated the foods immediately after they finished eating the yogurt. The results showed that sensory-specific satiety differs across age groups (see **Figure 4**). Subjects over the age of 65 did not show a greater decrease in the rating of the pleasantness of the taste of the food they had consumed compared with ratings of the uneaten foods, that is, they did not show sensory-specific satiety for the taste of the food they had eaten.

It is not clear why the elderly did not show sensory-specific satiety, but it did not appear to be related simply to a loss of sensory function. At the start of the tests, before eating the yogurt, the elderly subjects rated the sensory properties of the test foods as pleasant, as did the other groups. Although the elderly subjects showed the typical decline with age in

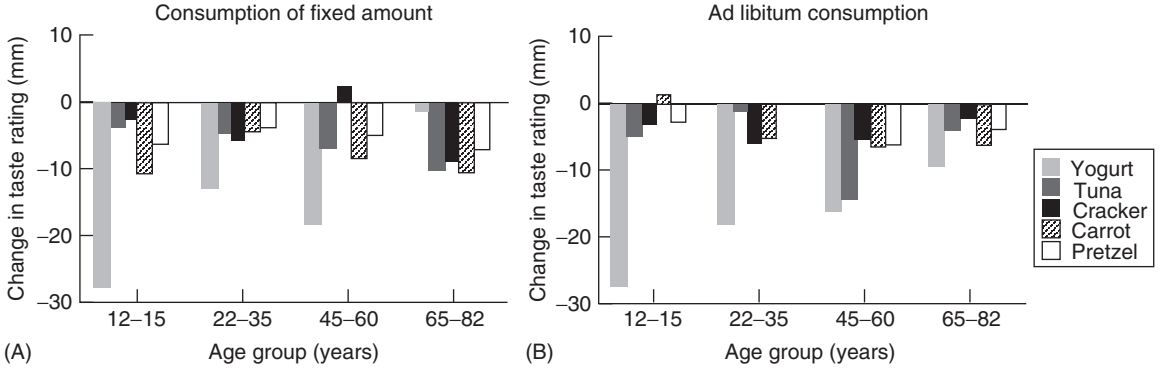

Figure 4 Mean changes in ratings for each of the foods sampled of the pleasantness of the taste of that food from just before to just after eating either 300 g (A) or ad libitum (B) amounts of yogurt by different age groups. This shows that sensory-specific satiety, or the change in pleasantness of the food consumed (yogurt) compared with those not consumed, declines with increasing age. Reproduced with permission from Rolls BJ, and McDermott TM (1991) Effects of age on sensory-specific satiety. *American Journal of Clinical Nutrition* 54: 988–996, 1991. Copyright American Society for Clinical Nutrition.

the ability to identify odors, this did not correlate with sensory-specific satiety for either taste or odor. This was surprising because it seemed likely that changes in the pleasantness of the taste or odor of a food would depend to some extent upon olfactory function. Further studies relating sensory impairments to the changing hedonic response to foods will be of interest because the mechanisms underlying sensory-specific satiety are not well understood. It is likely that in addition to a sensory component, there is a cognitive component related to the knowledge that a food has just been consumed. It is not clear why the elderly would differ in this respect, but it may be related to a decreased desire for change of all types.

An impairment in sensory-specific satiety would be expected to be associated both with consumption of monotonous diets and with a failure to increase the amount consumed in response to variety in the diet. A recent study showed that the elderly are insensitive to the stimulatory effect of variety on fluid intake. Elderly subjects drank similar amounts following 24 h of dehydration when they were offered just one beverage (water) and when they were offered four beverages (water, mineral water, cola, orange juice). Although a young control group was not tested, a previous study in young people showed that more fluid was consumed with a variety of drinks than with just one drink. Also, young subjects ate more when a variety of foods was available than when offered just one food, and this increase in intake was related to sensory-specific satiety. Thus, a failure to experience sensory-specific satiety would be expected to be associated not only with a monotonous diet, but also with a lower caloric intake in a varied meal. More studies are needed to examine how age-related changes in sensory-specific satiety influence variety in the diet and food intake, both in experimental situations and in the natural environment. Variety in the diet has been found to be associated with better health in the elderly, and further studies could suggest strategies for increasing the variety in the diets of elderly individuals and in improving their nutritional status.

Socioeconomic Issues

Low food intake in the elderly can be accounted for by multiple factors, ranging from primary aging to changed social and economic circumstances. In several studies of the elderly, a majority indicated a recent change in food habits for reasons of health, changes in living status, health beliefs, or simply because of a change in finances. Living arrangements, social isolation, and no socialization at meals may play a role. The living arrangements of older individuals can affect their diet quality. More men living alone consumed a poor-quality diet than did men living with a spouse, particularly those 75 years of age or older. The main effect of living alone was to decrease the amount of energy consumed rather than the types of foods chosen. Bereavement was found to be associated with negative effects on nutrient intakes by changing the social environment and altering the social meaning of eating (*see* Bereavement and Loss).

Education and other socioeconomic issues appear to play a major role. In a recent study of 152 women aged 85–94 years, old age did not have an adverse effect on food or nutrient intakes. The oldest women reported eating a similar or greater number of weekly servings of fruits, vegetables, dairy products, meats, and sweets as did women aged 64–85 years. On the other hand, education level did have a major impact on nutrient intakes. Women with education beyond high school reported higher intakes of selected vitamins and minerals than did less educated women.

Some of the nutritional problems can be remedied to some extent by providing home-delivered meals and groceries and convenience foods of high nutrient density. Increasing socialization at meals could also have a significant impact, although this has not been investigated experimentally in the elderly. Studies in young men and women showed that they ate up to 50% more when eating dinner with three friends than when they ate the same meal alone. The nutrient composition of the diet was not affected. Of interest was the finding that eating with strangers did not increase intake at dinner compared to eating alone. Thus, although socialization at meals could increase intake of the elderly, this may depend on the type of social interactions that take place.

Diet-related attitudes and beliefs may also influence food habits. Some studies have identified taste, health beliefs, familiarity, price, convenience, and prestige as being among the key social determinants of food selection. Older people are generally more concerned with health issues, notably energy and fat consumption, and with food costs. Saving time is not a major issue. Single elderly women are most concerned about food costs.

Pathological concern with BW and dieting has also been observed among elderly women. There have been concerns that age-related anorexia among the elderly resembles the psychiatric syndrome of anorexia nervosa, more commonly reported among young women. Anorexia nervosa is characterized by refusal to maintain a minimum BW, disturbance of body image, morbid fear of fatness, and a preoccupation with food and eating. Endocrine abnormalities

are also seen, the most frequent of which is amenorrhea, or cessation of menstruation. A survey of elderly individuals who were below 90% of average BW indicated that pathological responses on a questionnaire used to assess eating-related attitudes were seen in 9% of those tested. Abnormal attitudes included a display of self-control around food, avoiding eating when hungry, enjoying having an empty stomach, engaging in dieting behavior, and being terrified about being overweight. Case reports of anorexia nervosa among elderly women have been described in the literature. The patients were described as having all of the features of the diagnosis except for the amenorrhea. Typically anorexia nervosa is associated with other conditions, particularly depression. Depression in the elderly could exacerbate their anorexia.

Intervention Strategies

Ideally, diets designed for the elderly should provide nutrient-dense foods. Although energy needs are reduced in old age, dietary requirements for protein, vitamins, and minerals are increased. For example, studies of elderly women in nursing homes reported that calcium intakes were at best marginal in that age group. Women living at home consumed even less calcium than those in nursing homes. As a result, dietary strategies have focused on the consumption of fortified or nutrient-dense foods.

The impaired regulation of food intake seen with aging could influence responses to high-energy nutritional supplements. The elderly are less likely than younger individuals to compensate for the energy in supplements by reducing intake of other foods. This was confirmed in the study in which healthy elderly men did not reduce intake at lunch following high-energy yogurt consumed 30 min earlier. The older men had significantly lower baseline lunch intakes than the younger men, but by preceding the meal with a high-energy supplement the total intake for the meal was increased significantly and to a level comparable to that of the younger men. Thus, dietary supplementation may be an important approach to enhancing the energy intake of the elderly. However, not all of the available data indicate that supplementation is beneficial. In a recent study of frail elderly men and women (mean age 87), daily evening supplementation for 10 weeks with a high-energy multinutrient liquid increased total daily energy intake only when combined with exercise. Participants not exercising decreased intake to compensate for the energy in the supplement. This result differs from that of findings from other laboratories. For example, in one study when elderly patients with poor appetites were given two different nutritionally complete liquid diets to consume freely for 10 days, energy intake was increased significantly. It appeared that there was little compensation for the energy from the supplements. In another study of elderly participants at risk of malnutrition, dietary supplementation was found to increase daily energy intake and weight gain over a 12-week period. Thus, most studies indicate that nutrient-dense supplements can increase energy intake and improve the nutritional status of the elderly. Future studies should systematically determine the critical parameters (type, amount, or energy density of the supplement) associated with supplementation that influence energy intake.

There are a number of other possible strategies for optimizing the diets of the elderly. One strategy involves sensory supplementation. Flavor amplification and flavor enhancement have been mentioned as ways of increasing food palatability to counteract sensory deficits. However, there is little evidence that moderate sensory deficits as opposed to sensory distortions affect nutritional status. Rather, studies indicate that the sensory system in healthy older people is relatively robust and that sensory deficits are not always linked to poor nutrition and weight loss. Although age-related sensory losses undoubtedly detract from the quality of life, no evidence so far has linked them to impaired nutritional status and ill health.

Such narrowing of dietary choices as has been observed may have been due to a deliberate restriction of calories, fat, sugar, and salt. People over the age of 60 are concerned with coronary heart disease, hypertension, and diabetes, and many follow medically prescribed diets that are low in fat, sugar, and salt. Foods containing intense sweeteners and fat substitutes might fulfill a special need. At present, low-calorie foods are used chiefly by people wishing to lose weight. This allows dieters to reduce energy intakes, without narrowing food choices and compromising the hedonic value of food. For elderly individuals who have health problems associated with obesity, such foods can be of benefit. However, many elderly people have energy intakes that are too low to meet energy requirements. Clearly, choosing reduced-calorie products could exacerbate problems of anorexia and low-energy intake in these individuals, especially because they are less likely to compensate for changes in the energy content of foods. Given the growing size of the elderly population, the market for such foods is increasing. A survey by the Calorie Control Council in 1991 indicated that consumers age 60 and over showed the most dramatic increase in the use of low-calorie, sugar-free foods

and beverages. Because the elderly are heterogeneous in terms of their BW and nutritional requirements, they must be appropriately informed about how energy-modified foods fit into their diets. Regardless of their BW, if they consume reduced-calorie foods these should be of high nutrient density.

A number of strategies for increasing daily energy intakes involve addressing social and economic problems and changing dietary behaviors. Community nutrition programs aimed at the elderly provide subsidized meals both in the home and at congregate sites. Such programs help to overcome some of the problems associated with nutritional difficulties stemming from low income, impaired mobility, loneliness, and lack of socialization at meals. Other strategies involve managing dental and medical problems that affect food intake and encouraging consumption of foods that are readily chewed and digested. Many elderly individuals have swallowing problems that require individualized diets that provide foods of textures that promote consumption. Some elderly individuals, because of low appetite and impaired thirst, must be prompted to eat and drink. Clearly management of the nutritional problems associated with aging requires sensitivity to a wide range of physical, psychological, and environmental influences on food and fluid intake. Future interven tion studies should focus on optimal intervention strategies for improving the nutritional status of both community-dwelling and institutionalized elderly individuals.

See also: Body: Composition, Weight, Height, and Build; Exercise and Physical Activity; Gastrointestinal System: Function and Dysfunction; Homeostasis, Homeodynamics and Aging; Self-Regulation, Health, and Behavior; Smell and Taste; Thirst and Hydration.

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Disability, Functional Status and Activities of Daily Living

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Glossary

Disability – An individual's physical, cognitive, or psychological incapacity to function within a given social and environmental context.

Functional Limitations – Limitations in performance at the level of the whole organism or person.

Impairment – A loss or abnormality at the tissue, organ, and body system level.

Introduction

Older age is characterized by increased susceptibility to disease, functional decline, and cognitive impairment, and, therefore, older persons have multiple comorbidities and disabilities and are often high consumers of health-care resources, particularly at the end of life. Thus, measuring and understanding disability are essential in developing and implementing preventive, therapeutic, and rehabilitative strategies that are urgently needed to improve the quality of life of millions of suffering individuals and to reduce, at least in part, the physical, psychological, and financial burden of caring for the disabled that currently rests on the shoulders of informal caregivers and the health-care system.

Identifying people with disability and measuring disability across a wide spectrum of severity are challenging tasks. Disability refers to an individual's capacity to function within a given social and

environmental context. Thus, disability is not an attribute of an individual; rather, it exists when an individual's physical, cognitive, or psychological capacity does not fit the demands of a given task within a specific environment. An individual's assessment of the difficulty in performing a task may be affected both by self-perception and by adaptations made to compensate for, or minimize, a decline in function. Therefore, self-perception of difficulty provides information on impending disability that is not detected as the need for help of another person because it is already compensated for. For example, an individual who has installed rails in the bath, when questioned, reports no difficulty when bathing. Thus, information on personal and environmental adaptations to disability, and the perception of making an effort while performing activities of daily living, can provide more accurate information than asking about difficulty alone. It is important to point out that even in very old individuals, disability is not a static condition: many people recover from a disease or injury (for example, after a fall or a stroke), while others experience wide fluctuations in their physical and cognitive function. As a consequence, measuring disability has no unique gold standard.

The subsequent sections of this article deal with why and how disability is measured. It begins by delineating how the paradigm that maps the different components of the pathway from disease to disability has evolved from the initial World Health Organization (WHO) model, its customized version proposed by Nagi and the Institute of Medicine, and, more recently, the International Classification of Functioning, Disability, and Health (ICF). Then, it lists selected well-established instruments that operationalize the elements of these paradigms in measurement tools used in real life. The final section of the article addresses some of the special problems that may be encountered using disability measures in geriatric research, with particular attention paid to clinical trials.

Why Measure Disability in Older Persons?

Without pretense of exhaustiveness, a list of the main reasons for measuring disability in older persons is presented in **Table 1**.

First and foremost, measures of disability in older persons provide information on health status that is independent and superior to any other measures from more traditional, medical, disease-oriented approaches. There is consistent evidence that a large percentage of disability in older persons is the direct consequence of chronic morbidity and, especially, comorbidity. A stroke, a massive myocardial infarction, pneumonia, and a hip fracture are catastrophic events that often cause substantial disability. Conversely, in the year when they develop severe disability, less than one-fourth of older individuals have an acute diagnosis that requires hospital admission, while in the others no specific precipitating disease can be identified. Perhaps even more surprising, older persons affected by comorbidity are more likely to report disability than age-matched individuals free of these diseases, and the risk gradually increases with the number of coexisting diagnoses. Thus, disability summarizes the balance between the negative impact of multiple medical conditions of varying severity and the overall health and vitality of the individual. Capturing the same information by traditional measures of health status is almost impossible because coexisting diseases may occur in an almost infinite number of combinations, relative severity, and synergistic and compensatory patterns.

Targeting the medical condition as the priority for treatment is most likely to have an effect on the patient's present and future functional status. In older individuals, the transition from the active to the disabled portion of their life marks a critical point in their everyday experience. Active life expectancy is generally considered a major indicator of health status at a population level and the gold standard outcome of any intervention aimed at improving the health and quality of life of older individuals.

Table 1 Main reasons for measuring disability in the older population

1. Assessing disability provides information on global health status of older individuals, which is independent of other disease-oriented measures of health
2. Assessing disability provides important prognostic information on multiple negative health-related outcomes
3. Assessing disability helps to estimate the type and amount of care needed currently and/or in the immediate future
4. Assessing disability may be important for legal purposes and to establish priorities in the allocation of support services
5. Assessing disability informs decisions regarding the current and future health-care needs of older persons. From an epidemiological perspective, measuring disability is also essential for studying predisposing risk factors and subsequent precipitants
6. A measure of disability should be considered the gold standard in any clinical trial that, indirectly or directly, is aimed at improving quality of life in the older population

Measures of functional status provide important prognostic information on multiple negative health outcomes, including risk of disability progression, health-care utilization, nursing home admission, and death. Performing a simple test of the lower extremity provides information on the risk of developing disability in basic activities of daily living (BADLs) superior to any known biomedical and clinical marker of risk. Medical oncologists realized this concept long ago. The Karnofsky performance status scale was originally designed to measure the level of patients' activity and requirement for assistance but was soon introduced as an important effect modifier in most prognostic indexes created for different types of cancers and for the stratification of cancer patients enrolled in clinical trials. The performance status is still widely used for prognostic purposes in oncology, although recently more refined measures of functional status specifically tailored to cancer patients have been introduced.

Assessing disability provides unique information on the type and amount of care needed, currently and in the immediate future, for older disabled individuals. Measuring disability helps to develop and optimize a detailed care plan, track the clinical progression of the patient, and, especially in rehabilitation, understand whether the patient is still improving or has plateaued. In community-dwelling older individuals, the assessment of care needs is essential to establish the allocation of adequate services. For example, eligibility for nursing home admission or home care is often based on the level of disability and autonomy. In addition, level of disability determines the optimal balance between formal and informal care, in terms of providing the best care for the disabled person while minimizing stress on the caregiver and reducing the risk of institutionalization.

Assessing disability is important for legal purposes such as insurance, medical reimbursement, driving eligibility, and others.

Measures of disability collected at the population level are often used to inform decisions regarding the current and future health-care needs of older persons and to forecast the likely demand for long-term care and support services. From an epidemiological perspective, measuring disability is essential in identifying predisposing risk factors and subsequent precipitants for accelerated functional decline. In general, rates of disability increase with age and across age groups, and women tend to have higher rates and severity of disability than men. Unfortunately, very little data exist on the fraction of disability that is attributable to different causes, and the different risks of disability between men and women are also not well understood.

From a research perspective, measuring disability in epidemiological and observational studies is important for identifying risk factors for disability that can be targeted for preventive interventions. A comprehensive list of major risk factors for old age disability is still in the stage of development. In particular, risk factors for transient and short-term disability and risk factors for disability in specific tasks are the focus of studies now in the field.

Finally, measures of disability should be considered the gold standard in any clinical trial that, indirectly or directly, aims to improve quality of life in the older population. There is consensus that functional status, particularly level of disability in ADLs, is the most important condition affecting perceived quality of life in the adult and older population.

Operational Paradigms of the Causal Pathway to Disability in Older Persons

In the past two decades, many tools for measuring disability have been developed and validated, including self-report batteries as well as objective, standardized tests of performance. The availability of many different instruments contrasts with the lack of a consistent framework for organizing and categorizing types of measure. A basic approach is to classify measures that track different stages along the disablement process according to whether they identify impairments, functional limitations, or disability.

The WHO model of Impairment, Disability and Handicap (WHO ICIDH) was perhaps the first serious and systematic attempt to classify factors that lead to the condition of illness, defined as the subjective and functional experience of disease (**Figure 1**). At the foundation of the pathway is pathology, which

Figure 1 Theoretical pathway from disease to disability traditionally used in geriatric medicine and research. Top, WHO (1980); bottom, Nagi (1965) and Institute of Medicine (1991).

is defined as any abnormality of macroscopic, microscopic, or biochemical structure or function affecting an organ or organ system. The second step of the pathway is impairment, defined as any abnormality of structure or function at the whole organism level, independent of any specific environment, symptom, or sign. At the third step is disability, which derives from the interaction between the organism and the environment and is defined as any change or restriction in an individual's goal-directed behavior or behavioral repertoire, usually manifested as dependence. Finally, handicap is defined as any alteration in a person's status (position) in society, including alterations in roles. Each level of the pathway should be considered as independent and may or may not be determined by the previous level and/or cause the successive level. For example, coronary heart disease pathology may not be followed by any impairment, disability, or handicap.

The categories of the ICIHD model are appealing because they create a taxonomy of functional measures. However, translating this theory into practice has proven to be difficult. Measuring the impact of single or multiple impairments on entire body function is almost impossible when the effect of the environment needs to be considered. For example, in patients enrolled in a hospital rehabilitation program, progression of physical function improvement should be evaluated with performance-based measures referenced to a standardized environment and then again after the patient returns to his or her home, with measures that capture the effect of the environment. The discrepancy between these two measures provides information on the potential gain that can be gathered by reducing environmental challenges. The value of using the concept of handicap has always been hampered by its difficult practical applicability to the elderly, the tendency to consider an almost exclusive environmental approach to handicap in health-care services, and the different (somewhat negative) notion attached to the word handicap in different contexts.

Some of these limitations were overcome by the active pathology, impairment, functional limitations, and disability model proposed in the early 1960s by the sociologist Saad Nagi and further refined in 1991 by the Institute of Medicine. According to Nagi, functional limitations are defined as limitations in performance at the level of the whole organism or person. In contrast, disability is defined as limitation in performance of socially defined roles and tasks within a socio-cultural and physical environment. Thus, Nagi views the concept of disability as representing the gap between a person's capabilities and the demands created by the social and physical environments and is therefore consistent with the traditional approach to rehabilitation (**Figures 1 and 2**).

For Nagi, active pathology involves the interruption of normal cellular processes and the simultaneous homeostatic efforts of the organism to regain a normal state, a concept that is extraordinarily compatible with the current view on the pathogenesis of age-related frailty. Impairment refers to a loss or abnormality at the tissue, organ, and body system level. To describe the distinct consequences of pathology at the level of the individual, Nagi uses the term functional limitations to represent restrictions in basic performance. Verbrugge and Jette attempted to operationalize Nagi's disablement model to attainable measures. A further elaboration of Nagi's conceptual view of disability is contained in the Institute of Medicine report *Disability in America*. An important advantage of utilizing different definitions for functional limitations and disabilities, as proposed by

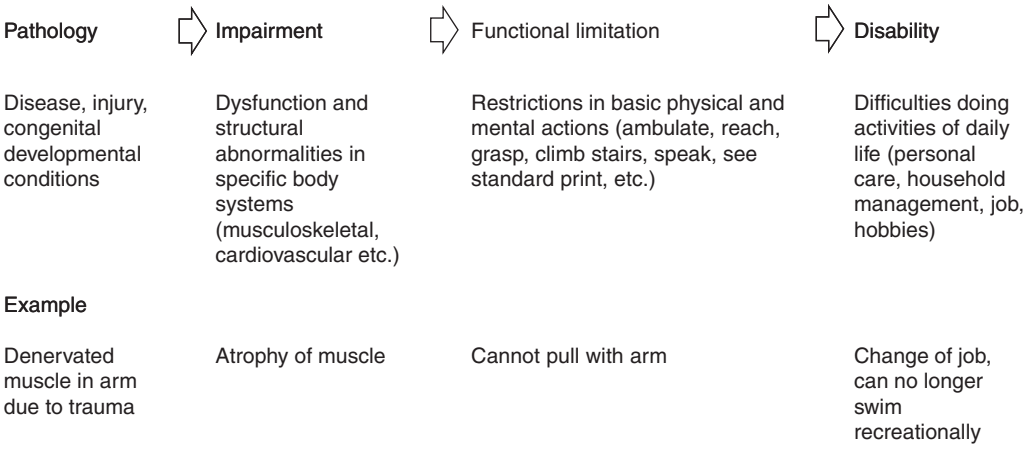

Figure 2 Theoretical pathway from disease to disability proposed by Nagi (1965), with operational definitions by Verbrugge and Jette (1994) and an example proposed in the Institute of Medicine report *Disability in America* (1991).

Nagi, is that they can be considered as sequential steps on the pathway from disease to disability. The validity of this theoretical pathway is supported by a large body of literature, and it is becoming evident that by utilizing this pathway we can address practical issues of care and prevention that can have a real impact on health outcomes.

In response to criticisms of the ICIDH classification system, in 2001 the WHO released a largely revised version under a new name, the International Classification of Functioning, Disability and Health (ICF) (**Figure 3**). The ICF is a clear shift in the paradigm of measuring disability: from describing disability, impairment, and handicap in terms of diminishments to describing body structure, functioning, activities, and participation in an objective way. In the ICF, the term functioning refers to all body functions, activities, and participation, while the term disability deals with the interaction between impairments and externally imposed activity limitations or participation restrictions (**Figure 3**). Furthermore, disability and functioning are considered outcomes of interactions between health conditions and contextual factors such as social attitudes, architectural characteristics, gender, age, and coping styles. Four main levels of human functioning are categorized by the ICF: the body or body part level, the whole person level, the person in the environment level, and the whole person in a social context level. The organ (pathology) level is similar to medical assessment of disease and disease severity, which is an expansion of the ICD classification. The whole personal level corresponds to the impairment approach, which consists of collecting information on the direct consequences of disease, disorders, and injuries and establishes the need for medical and rehabilitative services. The impairment approach ignores the fact that levels of disability cannot be inferred from the presence of an impairment, which leads to a tendency to underreport. The person in the environment approach is meant to directly acquire information about the day-to-day life of persons with disabilities in order to evaluate the need for social and support services. The need to develop an exhaustive list of important daily life activities and the tendency to consider disability as unidimensional (level of disability in different activities can be aggregated in a single score) are the main limits of this approach. A further limitation, which is addressed in the subsequent, hierarchical ICF environmental factor approach, is the lack of consideration for facilitators and barriers that may profoundly impact on the person's functional status. For the ICF, the interaction between the personal, physical, and social components results in a unique combination of factors that has a specific effect on the well-being of the individual (**Figure 3**). Since the ICF is still in a stage of development, this article uses a classification of functional status measures according to the Nagi model, therefore extending the approach already attempted by Verbrugge and Jette.

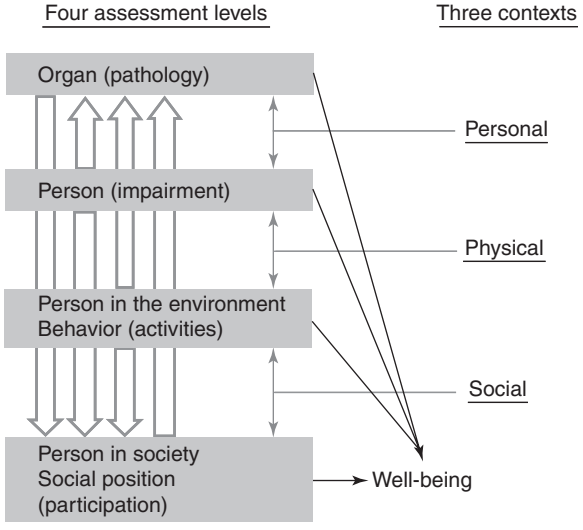

Figure 3 The International Classification of Functioning, Disability, and Health (ICF) model of illness (see text)

How is Disability Measured in Older Persons?

The following description of measuring disability is limited to selected tools that are most likely to be useful in clinical practice and in research projects in frail older persons. For each instrument, a brief description and some notes are reported. Instruments for measuring functional limitations and instruments for measuring disability are described separately. As a rough generalization, measures of functional limitation tend to be objective and performance based, while measures of disability tend to be self-reported. Common measures of functional limitation are listed in **Table 2**, and measures of disability are listed in **Table 3**.

Index of Independence in Activities of Daily Living (ADLs)

The index of independence in ADLs is a question-and-answer instrument. A dichotomous rating (dependent or independent) of six ADL functions (in order of decreasing dependency), bathing, dressing, going to the toilet, transferring from bed to chair, continence, and feeding, are rated on a three-point scale of independence and with reference to the past 2 weeks. This tool has been used for so long and in so

Table 2 Examples of tools used to assess functional limitations[a]

Assessment tool	*Assessment method*
Upper extermity	
Purdue Pegboard (Purdue Research Foundation)	Objective
Performance test aimed at assessing the coordination of gross movement of hands, fingers, arms, and find fingertips dexterity	
Timed Manual Performance (TMP)	Objective
Used in evaluation of manual dexterity and/or cognitive function of older persons, which is a strong predictor of dependency, need for increased care, and institutionalization	
Disabilities of the Arm, Shoulder and Hand (DASH) Scale	Self-report
A 30-item questionnaire that was developed to evaluate symptoms and upper extremity functional status	
Upper Extremity Physical Performance Battery (UEPPB)	Objective
Combines three standard measures (William's hand test, hand signature, functional reach) and provides a composite score	
Multidimensional	
Physical Performance Test (PPT)	Objective
Commonly used measure of overall functional ability of older adults that predicts mortality, nursing home placement, and risk of falls	
Nagi Activities	Self-report
Includes nine basic activities to be used for reference in measuring functional limitations, which is strongly predictive of health-care utilization	
Rosow Breslau Activities	Self-report
Evaluates the relative difficulty of performing daily living tasks for persons with a high-level of physical function	
Physical Disability Index (PDI)	Objective
Mostly used in a clinical setting, by trained professionals, with assessment of the passive range of motion and strength in several joints and muscle groups of the upper and lower extremities	
SF-36 Physical Function	Self-report
A short-form health survey that is particularly useful for comparing general and specific populations rather than individuals	
Physical Capacity Evaluation (PCE)	Objective
Averages performance scores on 13 tasks chosen to represent musculoskeletal activities necessary to perform instrumental activities of daily living. Poor performance is associated with difficulty in performing ADLs	
Continuous-Scale Physical Functional Performance	Objective
Assesses maximal performance in tests mimicking ordinary ADLs in standard conditions and in a continuous sequence and is a good choice in outcome measures of interventional trials aimed at increasing endurance	
Lower extremity (including balance)	
EPESE Short Physical Performance Battery (SPPB)	Objective
A composite performance-based test that is strongly predictive of negative health-related outcomes, including disability, nursing home admission, mortality, hospitalization, and utilization of health-care resources	
Tinetti Gait and Balance Scale Test	Objective
Assesses balance and gait, with a poor score indicating high risk of falls	
Avlund Mobility Scale (AMS)	Self-report
Incorporates two subscales, Mob-T and Mob-H, in which a high score describes better functioning	
Timed Up and Go (TUG)	Objective
Provides a measure of motor skills essential for independent living, which has mostly been used in the hospital setting, especially in the evaluation of patients with neurological motor disorders	
Berg Balance Scale (BBS)	Objective
A commonly used measure of postural control and stability that evaluates performance on 14 tasks, with evidence of responsiveness following rehabilitation intervention for frail elders as well as individuals with neuromuscular impairment	
Functional Reach	Objective
Measures dynamic balance and is strongly associated with measurements of center of pressure excursion evaluated on a force platform. Studies have demonstrated that a reach of less than or equal to 6 inches indicates a high risk of falling	
Fitness/endurance	
Six-minute walk	Objective
Assesses exercise tolerance in adults with cardiac and respiratory conditions and exercise capacity in older adults, which predicts hospitalization and mortality in patients with left ventricular dysfunction and advanced lung disease	
Health ABC Long Corridor Walk	Objective
Measures cardiorespiratory fitness longitudinally in well-functioning older individuals, which additionally provides a valid estimate of peak VO_2 in older adults, therefore providing a safe assessment of fitness in clinical and research settings	

Table 2 (*Continued*)

Assessment tool	*Assessment method*
Functional Fitness Test Measures parameters associated with functional ability in daily life and evaluates the risk for future accelerated decline of physical function and helps to identify older adults at risk for mobility loss	Objective

[a] Note that both self-report and performance-based instruments are reported and that the list is limited to tolls that are not specific for functional limitations due to specific diseases.

Table 3 Examples of instruments used to measure disability in the older population

Index of Independence in Activities of Daily Living (ADLs)
The Extended Activity of Daily Living Scale
The Barthel Index
Functional Independence Measure (FIM)
Instrumental Activities of Daily Living (IADLs)
The Karnofsky Performance Status (PS)
The Minimum Data Set (MDS) Disability Scale
The Office of Population Census and Surveys (OPCS) Disability Scale
The Nottingham Health Profile Disability Scale
The Sickness Impact Profile (SIP) Disability Scale
The Health Assessment Questionnaire (HAQ) Disability Scale
The WHO Eleven-Country Study Disability Scale
Disability Adjusted Life Years (DALY)

many studies and care settings that it is generally considered the gold standard to which any other measure of disability should be compared. The index of ADLs has strong predictive validity for a number of negative health outcomes.

The Nottingham Extended Activity of Daily Living (ADL) Index

The Nottingham extended ADL index was established as a postal questionnaire to monitor the level of ADL disability in patients discharged into the community after rehabilitation, in particular after an acute stroke. The tool assesses 21 activities within four categories: mobility (e.g., do you walk over uneven ground?), kitchen activities (e.g., do you do the washing up?), domestic activities (e.g., do you do a full clothes wash?), and leisure activities (e.g., do you go out socially?). It is a simple, self-administered questionnaire that can be completed by the patient in approximately 10 min; it provides an extended ADL score that is highly correlated with more complex, self-reported interviewer-administered measures of disability.

The Barthel Index

The Barthel index is an ordinal scale that measures functional independence in the domains of personal care and mobility in patients with chronic, disabling conditions, especially in the rehabilitation settings. Two main versions exist: the original 10-item form and expanded 15-item version. The 10-item version is the most used; it includes evaluation of independency in feeding, moving from wheelchair to bed and return, grooming, transferring to and from a toilet, bathing, walking on a level surface, going up and down stairs, dressing, and continence of bowels and bladder. The Barthel index is used to assess disability and to monitor changes in disability over time. The scoring method takes into account whether the person evaluated receives help while doing each task. The scores for each of the items are summed to create a total score, with higher scores indicating higher levels of independency.

The Functional Independence Measure (FIM)

The FIM is an 18-item instrument measuring a person's level of disability in terms of burden of care. The FIM should be rated by the consensus opinion of a multidisciplinary team, but the evaluation is often performed by a single professional. Each item is rated from 1 (requiring total assistance) to 7 (completely independent). Three independent FIM scores can be generated by summing item scores: a total score (FIM total: 18 items), a motor score (FIM motor: eating, grooming, bathing, dressing – upper body, dressing – lower body, toileting, bladder management, bowel management, and transfers bed/chair/wheelchair, toilet, tub/shower, walk, stairs), and a cognitive score (FIM cognitive: auditory comprehension, verbal expression, social interaction, problem solving, and memory). Multiple studies support the reliability and validity of FIM scales in the older population.

The Instrumental Activities of Daily Living (IADLs)

Lawton and Brody introduced the concept of IADLs in 1969. IADLs were defined as abilities in activities physically and cognitively more complex but still important for independent life. The Lawton and Brody IADL scale includes seven activities: use of the telephone, traveling via car or public transportation, food or clothes shopping, meal preparation, housework, medication use, and management of money. Each criterion is graded as independent, assistance needed, or dependent.

The Karnofsky Performance Status

The Karnofsky score is a simple and rapid method to assess patients' performance in ADLs, which has been mostly used in medical oncology. The score has proven useful not only for following the course of the illness, but also for obtaining prognostic information. Patients with the highest (best) Karnofsky scores at the time of tumor diagnosis have the best survival and quality of life over the course of their illness. The scoring is subjectively assigned by a health professional based on the following hierarchical scale: 100 = normal, no evidence of disease; 90 = able to perform normal activity with only minor symptoms; 80 = normal activity with effort, some symptoms; 70 = able to care for self but unable to do normal activities; 60 = requires occasional assistance, care for most needs; 50 = requires considerable assistance; 40 = disabled, requires special assistance; 30 = severely disabled; 20 = very sick, requires active supportive treatment; 10 = moribund. Intermediate or even decimal scores can be assigned. The tool is named after David A. Karnofsky, who described the scale in 1949.

The Minimum Data Set (MDS) Disability Scale

The MDS is a standardized, primary screening and assessment tool of health status that measures physical, medical, psychological, and social functioning of nursing home residents. The general categories of data and health status items in the MDS include demographics and patient history, cognitive, communication/hearing, vision, mood/behavior patterns, psychosocial well-being, physical functioning, continence, disease diagnoses, health conditions, medications, nutritional and dental status, skin conditions, activity patterns, special treatments and procedures, and discharge potential. The disability subscale has a hierarchical structure and provides information that is highly correlated with other self-reported ADL assessment instruments. The MDS is administered regularly to all nursing home resident in the United States.

The Office of Population Census and Surveys (OPCS) Disability Scale

The OPCS disability scale was developed by the Office of Population Censuses and Surveys in England and derived from the WHO Classification of Impairments, Disabilities and Handicaps. This disability scale is perhaps the most comprehensive tool yet devised. However, it is mostly used in epidemiological research rather than for the evaluation of single patients. The scale evaluates 25 activities distributed among the following domains: behavior, locomotion, continence, intellectual functioning, dexterity, personal care, consciousness, communication, reaching and stretching, hearing, seeing, disfigurement, eating, and digestion.

The Nottingham Health Profile (NHP) Disability Scale

The NHP is a well-established health status measurement instrument. The NHP is a self-administered questionnaire developed in the United Kingdom in the late 1970s. The 45 items of this two-part questionnaire were selected from an original pool of more than 2000 statements about the impact of illness obtained from more than 700 patients. The instrument is widely used in many countries. The physical mobility subscale, which includes questions about disability in eight activities, is valid, reproducible, and responsive to changes.

The Sickness Impact Profile (SIP)

The SIP is a multidimensional measure of health status and the impact of sickness that has been extensively used in older individuals to describe and monitor health status. The scale consists of 136 items in 12 different categories: sleep and rest, emotional behavior, mobility, body care and movement, eating, ambulation, recreation and pastimes, social behavior, communication, alertness behavior, home management, and work. Questions in the mobility and ambulation categories have been used in many studies and provide information on both functional limitations and disability. Total, category-, and dimension-specific scores can be calculated, with higher scores representing greater dysfunction. In a landmark study, changes in functional status identified using the SIP appeared to be valid representations of true changes in health-related functional status.

The Health Assessment Questionnaire (HAQ) Disability Scale

The HAQ is a functional status developed by Fries *et al*. in 1980 and is mostly used in rheumatology, especially in clinical trials and observational outcome studies. The HAQ score is accepted by the US Food and Drug Administration for evaluation of the prevention of disability in chronically ill patients. A large portion of the HAQ concerns the evaluation of disability in ADLs and 14 questions relating to the use of aids and devices. It has been suggested that the HAQ score is best used to evaluate disability in patients who are severely ill.

The WHO Eleven-Country Study Disability Scale

This assessment instrument was derived by combining questions on disability in six basic and nine instrumental ADLs that were used to assess disability in the WHO Eleven-Country Study. A particular scoring algorithm was developed that classifies responses to the 15 questions into four domains of disability that are hierarchical in severity and are characterized by specific underlying physical impairments. The cross-cultural reliability of this model was verified in seven population-based samples of older persons living in five European countries.

Disability-Adjusted Life Years (DALY)

Disability-adjusted life years (DALY) have been proposed by the World Bank and the WHO as a measure of the global impact of disease on individual illness status. DALY combines information about morbidity and mortality and is expressed in terms of numbers of healthy years lost. In the DALY approach, each state of health is assigned a disability weighting on a scale from 0 (perfect health) to 1 (death), based on expertise and available data. To calculate the burden of a certain disease, the disability weighting is multiplied by the number of years lived in that health state and is added to the number of years lost due to that disease. The evaluation of DALY is only used at the level of large populations, mostly for addressing issues of international health policy. In spite of its wide use, the conceptual and technical basis for DALY's estimation has been seriously questioned.

Caveats Concerning the Use of Disability Measures in Older Persons

Although the introduction of measures of functional limitation has substantially improved the chances of studying and understanding the disablement process, several aspects of the complex relationships among aging, diseases, functional limitations, and disability are still unclear. For example, while a specific intervention may improve walking speed, the minimal degree of improvement needed to have a positive effect on the level of autonomy in ADLs is still unknown. Therefore, in spite of their objectivity, performance-based measures of physical function are still not used as primary outcomes in clinical trials. As experience with these tests accumulates, set points that define poor levels of functioning would have to be developed. For example, a gait speed of $\leqslant 0.4$ m/s is now recognized as representing a very substantial functional limitation with associated high risk of poor outcomes.

Although ascertainment of disability appears simple, a number of pitfalls may threaten reliability or validity of traditional self-reported measures. The threshold of physical ability below which older individuals perceive difficulty can be influenced by factors that change over time, such as social environment, economic status, cognition, and depression. Disability is dynamic and amenable to recovery and fluctuation. For some frail persons, the response to disability questions more accurately reflects what caregivers allow them to do than their actual capacity (perceived ability vs. actual performance in daily life). To avoid these problems, disability questions should be standardized and made applicable in the context of day-to-day life. Whether the question addresses potential capability or current behaviors should be specified. Whether disability is defined as perceived difficulty or as need for help should be determined, because only a small percentage of older persons who perceive difficulty in performing ADLs actually receive help in executing those tasks.

Objective, performance-based measures of functional limitation should be collected in parallel with self-reported measures of disability. However, it should be acknowledged that objective measures of functional limitation and self-reported measures of disability serve different purposes and, therefore, are complementary and not alternative assessments. In fact, performance at the time of assessment may underestimate (e.g., due to stress from testing) or overestimate (e.g., due to patients trying harder than usual) usual performance in normal daily life.

Further work is required to improve standardization and measurement of functional limitations. Although several functions, such as gait speed and time to complete a set number of chair rises, are commonly assessed, the technical aspects of doing these tests have not been standardized, making it difficult to directly compare function across studies. For example, gait speed may be tested at different distances. In some assessments, the participant is already walking when the starting line is reached, while in others, the test starts with both feet planted on the starting line, and different criteria are used for deciding when the participant actually crosses the finish line, as well. It would also be valuable if the instructions, motivational cues, and feedback after completion of the test were standardized.

The final challenge in moving forward with the use of disability measures is to reach a consensus on a standard core battery of assessment tools that should be used in specific clinical settings, residential accommodations, and research projects. The challenge is to support the validity of this battery with research

and to make it practical and easily interpretable by the clinician so that it can become a clinical vital sign of function that is routinely measured in practice.

Conclusions

The need for mapping specific measures of the different steps of the disablement process is well established both in geriatric medicine and in geriatric rehabilitation. Measurement tools for administrative and organizational purposes are also available for different types of settings. A number of projects that explore factors affecting the pathway from disease to disability in older persons are now in the field. This wide range of tools should be extensively utilized to guide interventions aimed at improving the quality of life of the older population, especially the segment that bears the burden of multiple morbidities, frailty, and disability. Research in this area is desperately needed.

See also: Adaptation; Dental Health; Frail Elderly; Human Factors Engineering and Ergonomics; Leisure; Mobility and Flexibility; Motor Control.

Further Reading

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DNA and Gene Expression

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Glossary

CpG Islands – Stretches of DNA, about 1–2 kb long, with an average GC content of about 60%, compared to 40% for the genome overall. CpG islands often surround the promoters of constitutively expressed genes.

DNA Damage – Changes in the DNA chemical structure induced by a variety of different chemical, physical, and biological agents.

DNA Repair – The complex of enzymatic systems to remove DNA damage and to restore the original situation.

DNA Replication – The process of copying the entire complement of genetic information.

DNA Transcription – The process of copying the genetic information encoded in a gene into mRNA.

Gene – The segment of DNA encoding a polypeptide chain; it includes regions immediately preceding and following the coding sequence as well as intervening sequences (introns) between individual coding sequences.

Genome – The coordinated ensemble of DNA and protein in the cell, carrying out all its genetic transactions. The human genome consists of approximately 6 billion base pairs of DNA distributed among 46 DNA–protein complexes termed chromosomes.

Intron – A transcribed but non-coding part of a gene, separating one exon (coding part) from another. Introns are removed from the transcript by splicing together the exons on either side of them.

Mutation – Change in the sequence of DNA in a genome that can involve a single base pair position (point mutation) or a rearrangement (deletions,

insertions, recombinations). The *in vivo* mutant frequency is defined as the frequency at which a mutated variant of the gene is found among unmutated copies.

PCR Amplification – An *in vitro* process used as a laboratory tool for copying DNA fragments in an amount sufficient for their analysis.

Promoter – The portion of a gene to which RNA polymerase must bind before transcription of the gene can begin.

Protein Translation – The process of producing a protein based on the mRNA code.

Repetitive DNA – A collective term for all the DNA sequences that occur more than once in the genome of an organism. Minisatellites are tandem repeats of a short unit occurring all over the genome (clustered at the telomeres). At a given minisatellite locus, the copy number can be highly variable and differ between 5 and 50 copies among different chromosomes.

Transcriptome – The complete set of mRNAs of a given cell or cell type.

Introduction

Genes are the units of inheritance. They reside in the genome as sequences of deoxyribonucleic acid (DNA), carrying the information representing a particular polypeptide. The DNA sequence of the human genome, as well as that of many other species, including mouse and rat, has been completely decoded. The human genome contains between 20 000 and 25 000 genes. In mammalian genomes, genes are clustered densely into small islands in desert-like expanses containing few or no genes. The information encoded in the genes is expressed, first by generating a single-stranded messenger RNA (mRNA) identical in sequence to one of the strands of the duplex DNA (RNA transcription), and then by converting the nucleotide sequence of the RNA into the sequence of amino acids comprising a protein (protein translation). While the protein-coding sequences of genes occupy only about 1% of the entire DNA sequence, their interruption by introns allows them to be spread over huge distances. Introns, which comprise 24% of the genomic sequence, are non-coding stretches of DNA that are transcribed, but eventually excised from the mRNA, thereby fusing the remaining parts, termed 'exons,' by a process called splicing, into the final protein-coding mRNA.

Genes are perpetuated (as in cell division or the generation of gametes) by a duplication process of the double-stranded DNA to give identical copies (DNA replication). A gene is a stable entity, but can suffer changes in its chemical structure or in its sequence. Sequence changes are called mutations, and may occur as a result of replication errors or mistakes made during the repair of chemical damage. The phenotypic results of mutations range from undetectable to lethal. Patterns of gene expression can undergo changes with time, either in a random fashion, for example, through genomic alterations, or in a programmed manner, as exemplified by the switching on and off of individual genes during development and differentiation. Aging is a process of change with time that is associated with increased loss of function, increased pathology, and increased susceptibility to disease. Although aging never fails to result in the death of the organism, the information encoded in its genes is perpetuated in the form of an immortal germline. A multitude of physiological, cellular, and molecular changes have been found to occur in aging individuals of various species. The relevance of many of these changes, with respect to possible causal relationships with age-related pathology and/or functional decline, is unclear at present. This is the case for most age-related changes in DNA and gene expression, which have been considered, alternatively, as the basic cause of aging or merely background noise against a predominantly pathophysiological process occurring at a higher level of organization. The question to be addressed in molecular gerontology is whether aging can be reduced to a finite number of molecular processes based on stochastic damage and/or genetically programmed events.

Underlying Theory

Background

Changes in genome organization and expression have long been considered as possible explanations for the general breakdown of structure and function during aging. Stochastic damage to DNA, the ultimate template, could lead to qualitative and/or quantitative changes in gene expression, resulting in random phenotypic alterations in individual cells with a loss of tissue function and multiple forms of pathology as potential consequences. Alternatively, age-related changes in gene expression could occur in a programmed fashion, resulting in phenotypic changes that are similar from cell to cell. In testing these two scenarios, which are not mutually exclusive, the following questions regarding aging-related changes need to be addressed: (1) what kind of alterations in the somatic genome and its translation into phenotypic information need to be considered; (2) do such

changes actually occur and can they be causally related to the aging phenotype; (3) what are the mechanisms by which these changes arise; and (4) what are the defense systems minimizing their effects?

Evolutionary Basis

While the mechanisms underlying age-related degeneration and death in various species still need to be uncovered, a consensus as to why and how we age has begun to emerge. It is now generally accepted that the time-dependent decrease in fitness in most multicellular organisms is non-adaptive; that is, it is not controlled by a purposeful genetic program similar to the control of development. Aging provides no specific advantage and most researchers now accept that age-related degeneration and death is ultimately due to the greater relative weight placed by natural selection on early survival or reproduction than on maintaining vigor at later ages. This is due to the scarcity of older individuals in natural populations owing to mortality caused by extrinsic hazards, which essentially prevents the manifestation of late age effects of genes. Consequently, such late effects of genes, whether positive or negative, will be ignored by natural selection.

Life span is often considered as the result of a trade-off between growth and reproduction on the one hand and somatic maintenance on the other. High extrinsic mortality would favor investment of scarce resources in early reproduction rather than somatic maintenance. Indeed, the so-called disposable soma optimizes rather than maximizes maintenance and repair activities to meet the requirements of the life time strategy of the organism. This suggests that organisms age as a result of the accumulation of unrepaired somatic damage due to their continuous exposure to damaging agents, such as free radicals, the toxic by-products of normal metabolism. Shifts in resource utilization towards increased investments in somatic maintenance would then lead to increased life span. This may have occurred over evolutionary time and could explain the emergence of long-lived mammalian species, such as humans. However, it could also happen more quickly by down-regulating growth and reproduction, for example, by caloric restriction. Caloric restriction is a very effective intervention that has been shown to increase life span in multiple species, including mammals. Other examples are laboratory strains of evolutionary distant organisms such as nematodes, fruit flies, and mice, in which life span can be increased causing a down-regulation of growth and reproduction. Examples are mutations that downregulate insulin signaling, growth hormone levels, and nutrient sensing. It is assumed that such downregulation facilitates a shift in resource allocation to longevity assurance processes, which occurs naturally in many species under adverse conditions when reproduction needs to be postponed. Indeed, life span is highly plastic and can be manipulated, as a function of different circumstances, by metabolic switches that can affect the levels of spontaneous somatic damage or the proportional effort that is devoted to somatic maintenance.

Not surprisingly, cells and the various macromolecular complexes that serve to provide for their function are generally considered as the main target of somatic damage accumulation in aging. Which of the major biomolecules –DNA, RNA, protein, lipids, and carbohydrates – would be the most important cellular targets? Some would argue for DNA in view of its unique role in transferring genetic information from cell to cell and from generation to generation. Others, however, would say that changes at the protein level can potentially influence all other macromolecular structures in the cell, including the DNA. Changes have been found at all levels, and the various pathways involved in the cell's macromolecular machinery and its maintenance and repair are so intertwined that no single molecule, system, or structure can be considered on its own (**Figure 1**). Nevertheless, there are some very good arguments for assigning a primary or predominant role to changes in DNA and gene expression.

First, a strong, logical argument for considering the DNA of the genome as the Achilles heel of an aging organism is the irreversibility of unwanted sequence changes in view of the lack of a back-up template. This is in contrast to RNA or proteins, which, at least in principle, can be easily replaced with the corresponding gene as a template. Indeed,

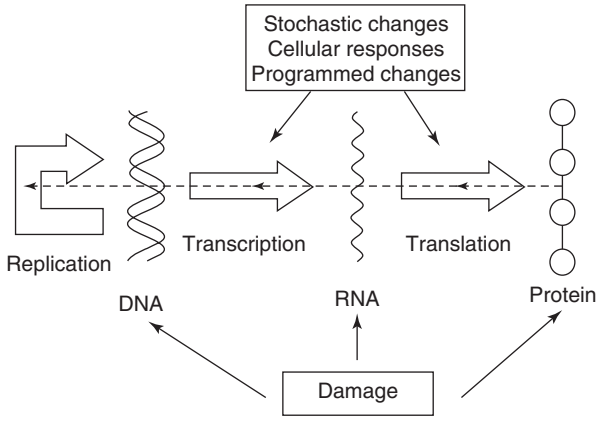

Figure 1 Flow of cellular information from DNA to protein (large arrows). The dotted reversed arrow indicates the influence proteins exert at all stages of the information flow. Thin solid arrows indicate the changes that can occur in the different molecules and their transactions.

the maintenance of genomic DNA is of crucial importance to survival because its alteration by mutation is essentially irreversible and has the potential to affect all downstream processes.

A second, powerful body of evidence for considering changes in DNA as critically important in driving the aging process involves the demonstrated association between heritable DNA repair defects in humans and premature aging. Such genetic disorders are termed segmental progeroid syndromes because they accelerate some but not all of the signs of normal aging (**Table 1**). While these disorders have been known for over a century and were from the beginning recognized as being associated with premature aging, it has only been recently discovered that in virtually all cases the cause is a heritable mutation in a gene that is involved in genome maintenance, i.e., the network of processes that maintain the integrity of the genome over chronological time and during cell division. This highlights the importance of DNA transactions (such as replication, repair, transcription, and recombination) for somatic maintenance during aging. The segmental progeroid syndrome that is most similar to normal aging is Werner syndrome (WS), caused by a defect in the WS gene (WRN), one of several highly conserved RecQ helicase genes that help to maintain genome stability. WS individuals prematurely develop characteristics of old age, such as atrophic skin, thin gray hair, osteoporosis, type II diabetes, cataracts, arteriosclerosis, and cancer.

Interestingly, mice harboring engineered genetic defects in genome maintenance often display multiple symptoms of premature aging. Indeed, genetic defects in few, if any, other systems than DNA repair and genome maintenance have been associated with premature aging.

What are the types of aging-related changes that can occur in biological macromolecules along the axis of the central dogma, i.e., DNA → RNA → protein? First of all, as realized early on, spontaneous errors may occur during the processes of replication, transcription, and translation. Chemical damage to all major biomolecules, from such sources as reactive oxygen species and various environmental agents, has been demonstrated to occur and may lead to loss of function. Random damage to DNA may affect transcription and can result in mutations as a consequence of errors during replication or repair. Mutations have the potential to result in permanent gene expression changes that are different from cell to cell.

Damage to DNA and other macromolecules in the cell can elicit powerful programmatic responses, such as DNA repair, apoptosis, cellular senescence, and other stress responses. The gene expression changes associated with these responses would be very similar from cell to cell. This may explain many of the consistent alterations in gene expression that have been observed in organs and tissues of animals during aging. Other consistent gene expression changes at old age could include delayed pleiotropic effects of developmental processes or rare postdevelopmental, programmatic changes in the elderly, selected during evolution when they influence the reproductive success of their kin.

It follows from the above that both stochastic and programmatic changes in DNA and gene expression can be expected to occur during aging. Age-related changes in DNA can be expected to be predominantly stochastic. That is, each specific alteration occurs as a relatively rare event, which essentially transforms each organ or tissue into a mosaic of cells. Each cell would have its unique set of 'genomic scars' that distinguishes it from all other cells. By contrast, age-related changes in gene expression can represent both programmatic and stochastic events. That is, while each aged cell can have its own unique set of

Table 1 Some of the best-known human segmental progeroid syndromes

Syndrome	*Incidence (per live birth)*	*Inheritance*	*Age of onset (years)*[a]	*Mean life span (years)*	*Genes*	*Defect*
Hutchinson-Gilford	$<$1/1 000 000	*De novo*	2	13	Lamin A	Nuclear stability, transcription?
Werner	$<$1/100 000	Autosomal recessive	25	50	WRN	DNA double-strand break repair
Cockayne	$\sim$1/100 000	Autosomal recessive	5	20	CSA, CSB, XPD, XPG	Transcription-coupled DNA excision repair
Ataxia telangiectasia	$\sim$1/60 000	Autosomal recessive	10	20	ATM	Response to DNA damage
Down	$\sim$1/1000	*De novo*	40	60	Trisomy 21	Gene dose imbalance

[a] The age when accelerated aging becomes apparent, as distinct from age at diagnosis.

up- and downregulated genes, consistent changes occurring in each cell of a tissue or organ should also be taken into consideration.

Changes in DNA

DNA Damage

Cellular DNA is continuously damaged by a variety of exogenous and endogenous physical, chemical, and biological agents (**Table 2**). Such damage includes breaks in the sugar-phosphate backbone of the DNA, both single-strand breaks and the highly toxic double-strand breaks, base loss, base adducts, methylation, deamination and inter- and intra-chromosomal cross-links. The main sources of endogenous DNA damage, which is now considered more important than exogenous damage, include hydrolysis and oxidation. Especially oxidation through reactive oxygen species (ROS), the by-product of oxidative phosphorylation and other normal, physiological processes, can induce a variety of chemical damage into cellular DNA. It has been estimated on the basis of urinary excretion of DNA adducts that oxidative damage to DNA alone occurs at a rate of 10^4 hits per cell per day in humans; in rodents the rate may be an order of magnitude higher. Exogenous damage can be a result of exposure to ultraviolet light, background ionizing radiation or environmental chemicals, such as polycyclic aromatic hydrocarbons.

As indicated by the occurrence of DNA adducts in the urine, most of the damage is repaired. However, repair is imperfect, which may lead to an increased steady state level of DNA damage. Evidence has been obtained that the steady state levels of several forms of DNA damage (e.g., breaks, oxidative damage) increase with age in both humans and rodents. Increases of a factor of approximately two to three in the rat liver have been reported for nuclear and mitochondrial DNA (mtDNA). The mitochondrial genome is much more susceptible to oxidative damage than the overall nuclear genome. mtDNA from the rat liver has more than 10 times the level of oxidative DNA damage than nuclear DNA from the same tissue. This may be explained by such factors as a less efficient DNA repair system to protect mtDNA, the close vicinity of the main source of ROS, or the lack of histone proteins to protect mtDNA. However, it is entirely possible that certain areas of the nuclear DNA also accumulate DNA damage much faster than the genome overall. Indeed, DNA repair efficiencies vary considerably between different types of DNA sequences, with actively transcribed genes being repaired best.

Table 2 Major causes of DNA damage

Endogenous
Hydrolysis
Reactive oxygen species
Nonenzymatic glycosylation
S-adenosyl-L-methionine (alkylation)
Steroid hormones, excitatory amino acids
Exogenous
Dietary factors (e.g., benzo[a]pyrene)
Lifestyle (e.g., smoking)
Environmental exposures (e.g., UV, ionizing radiation)

Thus, higher levels of DNA (oxidative) damage, especially in mtDNA, appear to be present in at least some organs of older humans and rodents. The question is whether this kind of chemical damage can by itself explain some of the age-dependent functional declines that have been reported, for example, by interfering with transcription. While DNA damage can certainly interfere with transcription, such direct interference is unlikely to have a major functional impact. First, after taking extensive precautions against artificially induced damage – a notorious problem in such studies – results from various investigators indicate very low amounts of oxidative DNA damage. For example, the most frequent oxidative lesion, 8-oxoguanine, appears to be present in tissues from old animals as one lesion per 10^6 undamaged guanines. It is unlikely that such low levels of altered DNA bases could exert an important effect. While in mtDNA the levels at old age are much higher, the many mtDNA copies provide ample opportunity to compensate for the loss.

Second, it is not always realized that instead of a genuine accumulation of DNA damage, it is the difference between induced and repaired DNA lesions that has been measured, that is, steady state levels of DNA damage. It is not possible to know whether a particular lesion detected today will still be present tomorrow. Hence, the possibility should be considered that any increase in DNA damage, unless it completely overwhelms all defense systems (which at the levels reported is extremely unlikely under normal conditions), has no functional consequences.

DNA chemical damage becomes highly relevant when a lesion is fixed in the form of a mutation, that is, when a chemical alteration in DNA structure, recognizable by DNA damage processing systems, is turned into an erroneous base sequence as a permanent part of the genetic heritage. Such DNA sequence changes are discussed in the next section.

DNA Sequence Changes

In contrast to DNA damage, DNA mutations are changes in a DNA sequence that can be transmitted to daughter cells. Hence, mutations are not altering

the DNA chemical structure, but merely its sequence organization. They can affect a gene, gene regulatory region, or some other non-coding part of the genome. Mutations are usually introduced as a consequence of errors made during replication or repair of a damaged DNA template. Mutations can vary from point mutations, involving single or very few base pairs, to large deletions, insertions (for example, due to the activity of mobile genetic elements), duplications, and inversions. In organisms with multiple chromosomes, DNA from one chromosome can be joined to another, and the actual chromosome number can be affected. Because mutations are rare and do not affect DNA chemical structure, they are not easy to detect and the total number of mutations in individual cells of an aged tissue cannot be quantified. Hence, while we know that DNA damage induces a variety of cellular responses, the possible impact on the aging process of its stochastic endpoint, i.e., the spectrum of DNA mutations, is unknown.

It is difficult to reliably quantify and characterize spontaneous mutations, but a variety of methods have emerged, including methods that can be applied to the *in vivo* situation, which allow some conclusions to be drawn. Both cytogenetic tests and the HPRT assay, which is based on the selectable inactivation of this X-linked gene, have indicated the accumulation of mutations with age in lymphocytes from both humans and mice. Using transgenic mouse models harboring reporter genes that can be analyzed in *Escherichia coli,* it has been demonstrated that mutations accumulate with age in most organs and tissues at rates that are tissue specific. A substantial fraction of those mutations, depending upon the tissue, appeared to be genome rearrangements, i.e., deletions, inversions, or translocations. Some of such mutations appeared to be very large, i.e., involving millions of base pairs of DNA, even in postmitotic tissues such as heart. Some areas of the genome, such as those areas containing repetitive DNA (e.g., telomeres), appeared to be especially vulnerable to sequence alterations. Notably, apart from the nuclear genome, the mitochondrial genome is also subject to a variety of DNA sequence changes. Indeed, similar to DNA damage, the mitochondrial genome accumulates mutations much more rapidly than the nuclear genome. Since there are many copies of mtDNA in each cell, prevention of mutation accumulation may be less urgent in this case. Similar arguments apply to the various repeat element families.

An important question involves the functional impact of the observed mutation load and its increase with age. For most organs the magnitude of the age-related increase was small, i.e., about twofold on average. However, the functional properties of an aging organ can become compromised, even if most of the cells still function optimally. We will see later how a relatively small number of stochastic events can lead to adverse effects on the transcriptome, i.e., the complete set of mRNAs in a given cell type.

Epigenetic Changes

The genome is the carrier not only of genetic information, encoded in the DNA, but also of epigenetic information, including differential methylation of DNA on cytosines and histone protein modifications. Epigenetic changes alter gene activity without modifying the DNA sequence and are essential to normal development. However, similar to DNA damage and mutations, random alterations in the epigenetic code can cause problems, for example, when they disable genes that suppress tumorigenesis. A well-characterized mechanism for the heritable propagation of epigenetic information is methylation of cytosine residues at carbon 5 of the pyrimidine ring, primarily at CpG sequences. Methylation can silence a nearby gene in the context of histone protein modification patterns. Histone modification, the 'histone code,' comprises a pattern of posttranslational modifications including acetylation, methylation, phosphorylation, and ubiquitination. Histones are the proteins responsible for higher-order DNA structure. At the lowest level of organization, the DNA of the genome is wrapped around an octamer of core histone proteins. This structure can be condensed into the tightly packaged solenoid structure or 30-nm fiber, which can be further arranged into loops. Such higher-order structure of the DNA of the genome appears to be under control of DNA methylation patterns and the histone code, faithful maintenance of which is important since ultimately they determine the accessibility to the gene promoter sequence of various transcription factors. In general, DNA methylation and histone deacetylation is associated with transcriptional silencing, while demethylation and histone hyperacetylation on lysines make the DNA more accessible for transcription and are therefore associated with active genes. Unmethylated CpG sequences are specifically found in the GC-rich sequences in promoter regions of housekeeping genes, i.e., genes that are constitutively expressed in all tissues. Such areas are called CpG islands.

Very little research on aging has been devoted to the higher-order structure of the genome and alterations therein. The results of such research have varied, but overall the level of methylation tends to decrease with aging in most vertebrate tissue. This appears to coincide with observed increases in

nucleosome spacing and a lower sensitivity to nucleases, pointing toward a general relaxation of DNA higher-order structure. These changes could be caused by DNA damage, which can alter histone–DNA binding, or mutations, which can alter the sequence environment in which the methylation and histone codes have to act. Age-related changes have also been reported in covalent modifications of histones and non-histone proteins in mammalian tissues, for example, phosphorylation, acetylation, and methylation. More recently a number of age-related changes in methylation, both hypermethylation and demethylation, have been observed in specific gene sequences.

Cellular Defense against DNA Changes

To summarize the preceding, there is abundant evidence for alterations in the DNA of the genome during aging. The frequency and spectrum of such events may vary from genomic region to genomic region and are also different between tissues. The mitochondrial genome and repeat elements, such as those at telomeres, especially seem to undergo mutations at a high rate. There are some isolated reports of high-frequency mutations in protein-coding genes. Defense against the time-dependent loss of DNA functional template takes place at various levels (**Table 3**). First, damage can be prevented at an early stage, for example, by the activity of antioxidant enzymes if ROS are the primary cause of the damage. Then, damage can be repaired through the complex system of genome maintenance pathways, restoring the original situation as far as possible. This includes the restoration of methylation patterns and the histone code, which also need to be faithfully propagated during cell division, similar to the DNA primary sequence. Finally, when all other defense systems threaten to be overwhelmed, the cell itself can either shut down its replicational machinery, termed replicative senescence, or be entirely eliminated by programmed cell death or apoptosis. In this sense apoptosis is the ultimate mechanism for the maintenance of phenotypic fidelity in multicellular organisms.

Table 3 Molecular and cellular defense systems

- Antioxidant defense
- DNA repair and genome maintenance
- The P450 superfamily of detoxifying systems
- Tumor-suppressor genes
- Heat shock and other stress proteins
- Regulatory cytokines (e.g., interferon, tumor necrosis factor, interleukins, other growth and regulatory factors)
- The immunoglobulin superfamily
- Apoptosis
- Cellular senescence

Naturally, cellular defense systems function well enough at early age. However, as predicted by the evolutionary theory of aging, there is no reason to assume that the preservation of the genetic material in the somatic tissues until long after the reproductive period has a high priority. The previously described aging-related DNA alterations are, therefore, not surprising. Moreover, although there is no evidence that repair activities are overwhelmed at old age, moderate declines in, for example, the rate of DNA repair have been reported. It should also be noted that cellular defense systems against DNA damage and other stresses can turn from anti-aging into pro-aging systems. For example, apoptosis and cellular senescence help to suppress cancer at early age, but possibly at the cost of promoting aging at later ages by exhausting progenitor or stem cell reservoirs. Likewise, a powerful response to infection undoubtedly has a high survival value, but may at later age contribute to inflammation.

The combination of suboptimal cellular defense systems and increased age can be expected to give rise to three major cellular endpoints: neoplastic transformation, cell death, and cellular senescence. The exponential increase in cancer during aging has been well documented and could be explained at least in part by increased DNA mutations and/or methylation. Cell death can be observed as atrophy in a variety of tissue systems in aging organisms and could be due to increased levels of DNA damage, inducing apoptosis. Cell transformation and cell death are not sufficient to explain age-related degeneration of an organism and its ultimate demise, however. Indeed, most manifestations of normal aging at the cellular level are probably due to an increasing fraction of senescent cells. While such cells could in part result from replicative senescence, i.e., the irreversible cessation of cell proliferative activity in response to genomic stress, senescence is defined here as a general loss of function. It would be important to know if such seemingly unaffected cells, which form the majority of tissue mass in old animals, are in reality irreversibly damaged cells with seriously dysfunctional patterns of gene expression.

It is too early at this stage to generate a definitive 'damage report' for the aging higher animal genome in terms of the total amount of information loss due to random DNA alterations of various kinds. For this purpose more quantitative data are needed on the occurrence of some well-defined genomic lesions in various cell types of humans or animals over their lifetime. On the basis of such data it should be possible to calculate the average amount of functional

DNA template that is lost with age. Then it should also be possible to predict whether the genomic scars of aging are sufficient to seriously influence patterns of gene expression to significantly affect cell and tissue functioning.

Changes in Gene Expression

General

Some general characteristics of changes in gene expression with age are listed in **Table 4** and are briefly discussed here. A general age-related decline in transcription, that is, overall RNA synthesis as measured by the incorporation of radiolabeled precursors into RNA, has been observed to occur in a wide variety of organisms. Because the total RNA content does not seem to change, a decline in RNA turnover has been proposed. A comparable decline has been found for protein translation, and because the levels of most proteins also seem to remain constant, a decline in protein turnover was suggested and subsequently found. The primary cause of such general declines in macromolecular synthesis and their ultimate consequence for the individual to cope with environmental stresses are unknown.

Most attention has been paid to the expression of individual genes with age. Although gene expression can also be controlled posttranscriptionally and posttranslationally, the relative concentrations of individual mRNAs primarily determine the cellular phenotype, and it would be important to gain insight into the kinds of changes occurring at this level. Different kinds of changes can be envisaged. Genes can become over- or underexpressed during aging, previously silent genes can become activated, and previously active genes can be silenced. One can also envisage qualitative changes, such as in RNA editing (i.e., sequence changes).

It is important to distinguish non-consistent from consistent changes in gene expression. Consistent changes are changes that are the same in every cell of a given type or group. They are usually under the control of a genetic program, for example, late pleiotropic effects of differentiation and development, long-term environmental influences (e.g., viruses), and/or responses to environmental damage. Plus, genuine programmed alterations, even at late age, cannot be ruled out. Non-consistent or stochastic changes in gene expression would be unique to each cell and can occur as a consequence of random events, such as DNA alterations or errors during RNA transcription.

Table 4 Observed changes in gene expression with age: general characteristics

- Decline of total transcriptional and translational activity
- Decrease in total RNA and protein turnover
- Changes in constitutive levels of many individual mRNAs and proteins
- Decrease in inducibility of various mRNAs and proteins (e.g., immediate early genes, acute phase proteins, P450, c-myc)

Consistent Changes in Gene Expression

Most of the interest in gene expression and aging has been devoted to consistent changes, that is, changes in the expression of a gene in the tissue overall. This is undoubtedly due to the difficulty in accurately analyzing individual cells for molecular alterations. While in the past a number of well-described consistent changes in the expression of individual genes have been reported, such as the hormonally regulated $\alpha 2\mu$ globulin gene and several acute phase protein genes in the rat and mouse liver, the field is now completely dominated by the use of microarrays. Microarrays of up to tens of thousands of cDNAs or oligonucleotides, specific for parts of individual mRNAs, attached to a glass slide can be hybridized with labeled probes, obtained from reverse transcribed RNA from tissues or cells of interest. Such relatively simple experiments permit the analysis of changes in expression of a large number of genes simultaneously. This technology has the ability to reveal common patterns of gene expression across different samples. For this purpose, genes have to be grouped in an approach called cluster analysis into genes with similar profiles of activity. Such genes may have related functions or may be regulated by common mechanisms. The structured gene functional categorization database, Gene Ontology (GO), provides the opportunity to partition genes into functional classes.

A number of studies in which transcriptomes of aged tissue were compared with those of young tissue have now been performed, mostly with aging rodents, but also with other model organisms, such as nematodes and fruit flies. While definite conclusions must wait for improvements to the design of microarray experiments and for ways to optimally interpret results of such global analysis tools, some general conclusions can be drawn. First, it is clear that a wealth of genes undergo aging-related alterations in mRNA level, both up- and downregulation. Then, it appears that many rodent tissues as well as nematodes and flies are characterized by increases in expression of genes involved in stress responses at old age. For example, the results of a meta-analysis of microarray gene expression data obtained from *Caenorhabditis elegans* and *Drosophila melanogaster*

appeared to confirm that while most aging-related changes in gene expression are species specific, there is a shared adult-onset expression program of genes involved in mitochondrial metabolism, DNA repair, catabolism, peptidolysis, and cellular transport. There may also be tissue specificities. For example, in mouse liver and heart, genes involved in lipid metabolism were downregulated, but this is not the case for skeletal muscle, in which predominantly genes involved in biosynthesis and protein turnover were found to be downregulated. Since some of the results published were deficient with respect to their design, and the interpretation of such comprehensive gene expressional alterations is still in its infancy, it is impossible to draw more detailed conclusions at this point in time.

Consistent changes in gene expression could have a number of possible causes. First, the possibility cannot be excluded that they do result from stochastic damage to DNA and/or proteins interfering with proper gene regulation. For example, genes in mutational hot spot regions could undergo downregulation at a high frequency, which would eventually affect all cells in the tissue. Second, many expressional changes could be the result of stress induction, for example, by DNA or protein oxidative damage. Gene expressional changes occurring at old age may be responses to processes (e.g., hormonal secretion) already determined during development. Such cascades are apparently initiated because they offer some advantage at young age. At later ages they could cause problems and actually be responsible for a number of age-related disorders (e.g., loss of androgen sensitivity due to a decrease in the androgen receptor gene or heart failure due to hemodynamic stress as a consequence of a downregulation of proto-oncogene expression). Finally, some consistent changes in gene expression at old age may actually be programmed as part of the normal life history strategy. A speculative example in humans, explaining their long postreproductive life span, involves age-related gene expressional changes that help improve the capacity to transfer information to the younger generation.

Non-consistent Changes in Gene Expression

Non-consistent changes in gene expression during aging include the possibility of random gene activation or inactivation as a direct effect of stochastic gene mutations. Dominant (in proto-oncogenes) and recessive (in tumor suppressor genes) mutations play an important role in cancer initiation and progression, and in that sense they are also indirectly relevant to aging. There is some doubt with respect to the importance of such recessive and dominant gene mutations in aging. Assuming a spontaneous mutant frequency of 1×10^{-4} in old cells on average (as mentioned earlier, there are large differences from locus to locus), one cell in 10 000 will have lost a particular gene. Such defects by themselves are unlikely to influence any given cellular function. In reality, most cellular functions are based on several genes rather than just one, which would increase the DNA functional target size. However, the effects of random gene inactivation are likely to be buffered by complementation of function between different enzymatic pathways, metabolic cooperation between cells and redundancy at the cellular and tissue level. Hence, is it possible that genomic alterations cause cancer but do not directly influence organ and tissue functions? To address this question we need to know more about how our genome is organized and how the activities of our genes are controlled.

In pondering the possible effects of stochastic genome alterations on the cellular transcriptome it is important to realize that the DNA sequences comprising the protein coding segments of a gene are not the only regions in the genome with relevance to function. A simple organism such as *E. coli* has about 4000 protein-coding genes, comprising almost 90% of its total sequence. Humans and mice have realized their increased structural and functional complexity not by dramatically increasing the number of their protein-coding genes, but merely by increasing the size and diversity of their transcriptomes. In humans and mice, almost half of the genome is transcribed. It is assumed that this non-coding transcribed part of the genome has a regulatory role, which is greatly facilitated by the unique single-stranded nature of RNA. Therefore, while only few spontaneous DNA alterations are likely to hit protein-coding regions, many more would be expected to affect gene regulatory regions. Large genome rearrangements are especially likely to adversely affect normal gene expression, for example, as a result of a gene dose effect (partial haploidization), or position effects due to reshuffling of long-distance gene regulatory interactions. Hence, rather than drastic gene expression alterations, which are likely to be rare, one would expect a multitude of slight changes in the expression levels of many genes that will slowly lead to increased heterogeneity of the transcriptome in aging cell populations.

Any functional effect of a random DNA alteration would be enormously enhanced through epistatic effects. For example, it has been demonstrated that haploinsufficiency of genes encoding transcription factors increases the probability of stochastic activation or inactivation of its target genes, varying from

relative insensitivity to gene dosage to complete loss of expression. The functional impact of such random alterations is likely to be cell type and tissue dependent, in the context of individual genetic make-up and environmental conditions. Each tissue or cell type has a unique set of active functional modules (groups of proteins that work together to execute a function), the activity of which is primarily determined by transcriptional regulation of the genes involved, with individual genetic, environmental, and lifestyle factors as modifiers. Random DNA alterations are likely to be tissue specific, possibly as a consequence of tissue function and the tissue-specific utilization of genome maintenance systems. While there is a chronic lack of quantitative data on well-defined genetic lesions in different organs and tissues with age, it is conceivable that the stochastic accumulation of DNA alterations by itself is sufficient to cause aging. A conceivable scenario is that the gradual accumulation of DNA alterations in an aging tissue, affecting patterns of gene regulation in a stochastic manner, eventually results in a mosaic of cells, varying from cells that escaped significant damage to cells with severe dysfunctions, neoplastically transformed cells, and cells that are dying. Indeed, using immunohistochemical analysis methods (which are not quantitative), random loss of gene activities has been reported. For example, an age-related increase of cardiomyocytes without cytochrome *c* oxidase in the human heart has been reported and was suggested to be caused by mutation accumulation in mtDNA. An age-related increase in hepatocytes, which had reactivated the gene ornithine transcarbamoylase on the inactive X chromosome, has been observed in mouse liver and was ascribed to an age-related reduction in DNA methylation. Finally, in mouse brain, a random loss of cells expressing estrogen receptor-α was reported at old age. Such findings suggest age-related defects in DNA and gene expression that are stochastic in nature and may well reflect a broad loss of genome integrity with age.

Another type of stochastic alteration in gene expression involves errors made during RNA transcription or protein translation. In 1963, not long after the discovery of the fundamental mechanism of protein biosynthesis, Leslie E. Orgel proposed that cellular aging may well involve the accumulation of defective enzymes as a result of an inherent inaccuracy of the translational machinery. This is generally known as the 'error catastrophe theory of aging and longevity', based on Orgel's realization that the faulty RNA and DNA polymerases, also resulting from translational errors, would lead to an exponential increase of defects in protein, RNA, and DNA, causing the collapse of the cellular machinery for information transfer. This idea is not supported by experimental evidence, but it can be argued that errors are random, with each cell acquiring a unique set of errors. Since current technology is geared towards analyzing mixtures of cells rather than individual cells, we may simply be unable to detect error catastrophes.

Transcriptional errors could result from defective RNA editing, which involves the alteration of the sequence of nucleotides in the RNA after it has been transcribed from DNA but before it is translated into protein. This is a normal process, which – like alternative splicing – is a mechanism to increase the number of different proteins available without the need to increase the number of genes in the genome. However, it is conceivable that aging-related defects in this process could lead to gene expressional alterations. (The same would apply to alternative splicing.) However, there is no evidence for RNA editing of genes participating in information transfer. There is evidence for an age accumulation of aberrant transcripts due to dinucleotide loss during or after transcription of several genes, including the vasopressin gene, the β-amyloid precursor protein gene, and the ubiquitin B gene. In view of the role of ubiquitin in tagging proteins destined for proteasomal degradation, its inactivation would suggest that abnormal proteins accumulate with age, which is in keeping with the Orgel hypothesis.

Finally, there is now a tendency to develop and apply methods for the comprehensive analysis of transcriptomes and proteomes in single cells, either isolated from their tissue of origin or *in situ*. This is important to address the issues raised earlier, which typically involve different sets of aging-related alterations in different cells. However, it is of more general importance to abandon the concept of an average cell, which is not a good reflection of reality. Indeed, tissue samples are invariably composed of different cells and cell types. Since the cellular composition of tissues may greatly change with age, it is important to adapt current analysis methods to the reality of the single cell.

Changes in Genome Organization and Expression: A Synthesis

Aging has been considered both as a programmed series of events and a stochastic process of damage accumulation. The evolutionary theory of aging is a logical explanation of senescent deterioration and death and excludes a genetic program that actively causes aging as a purposeful process. Nevertheless, it cannot be denied that aging has programmatic

aspects, as indicated by the many observed consistent and reproducible changes in gene expression. It seems important to reconcile the stochastic with the programmatic aspect of aging.

Such a reconciliation has been done before, namely, for cancer. Indeed, stochastic somatic mutations are the ultimate cause of a series of events in which the cancer phenotype becomes increasingly more malignant and eventually shows a number of consistent alterations when compared with normal tissue. Many possible pathways that lead from the actual mutational event to the progressed tumor have been unraveled. Thus far, this has not been the case for aging. The reason is that an aged individual, much more than a progressed cancer, is essentially a mosaic of cells; each individual cell in a tissue bears a different pattern of 'scars.' It is more difficult to explain this in terms of consistent patterns of phenotypic changes observed in a typical aged individual, but it is nevertheless possible.

Based on the data presently available, it is possible to see the contours of the aging genotype as a prelude to the aging phenotype. Rather than a catalog of useful genes interspersed with functionless DNA, each chromosome is now viewed as a complex information organelle with sophisticated maintenance and control systems. In this concept of a genome, each part has a function, even its non-protein-coding parts. Such a holistic view of the genome would assign a variety of functions to non-coding DNA (e.g., structural maintenance, gene regulation).

Having extended the target for age-related changes to the whole genome rather than to a number of individual genes, it is also necessary to address the question of what kind of genetic changes are likely to play a role in determining the aging phenotype. In this context it is important to realize the single most striking characteristic of mammalian genomes: redundancy of genetic information. The simplest form of redundancy is copy number. With many gene copies present, the effect of some loss has no immediate adverse effects. This could explain, for example, the increased accumulation of DNA damage and mutations in mtDNA, which has ample redundancy to compensate for such loss of undamaged DNA template. Other forms of redundancy include the fact that more than one gene may specify a given cellular function. Finally, the existence of metabolic and other cellular networks allows the cell to accomplish similar endpoints through multiple overlapping pathways.

On the basis of these insights it is unrealistic to interpret the occurrence of changes in DNA and gene expression in the context of unique genes with unique effects. Instead, as pointed out by the late Bernard Strehler, a more useful background for understanding aging would be in terms of a gradual loss of functional informational redundancy. Rather than the inactivation of unique genes with unique functions, one should think of an initially tolerable loss of genome structural integrity, which would become manifest as a loss of phenotypic flexibility. Indeed, rather than some form of massive loss of essential genes, it is more likely that aging is accompanied by a slow but inexorable loss of genetic redundancy. This would undoubtedly lead to subtle scattered changes in gene expression and in the efficiency of gene regulation. Although primarily a stochastic process, this would rapidly take on some programmatic characteristics. The continuous randomization of the genome, by alterations in genes or in regions important in their regulation, unequivocally triggers the cell to respond. This response is programmatic and consists of species-specific stress and repair systems.

It would be premature to consider errors in genetic transactions, i.e., replication, repair, transcription, and translation, possibly driven by chemical damage to informational macromolecules, as the major cause of aging in all multicellular organisms. As a model, it does no more than account for some of the observations that have been made. Nevertheless, DNA damage as the original driver of a universal process of aging has some inherent logic. After all, damage to nucleic acids is the most ancient example of damage accumulation in the living world. Ever since the first replicators, genetic damage posed both a fundamental problem and an opportunity for living systems. A problem, because genetic damage essentially prevents the perpetuation of life, since it interferes with replication (and transcription); an opportunity, because it allows the generation of genetic variation through errors in replicating a damaged template, thereby facilitating evolutionary change. As we have seen, genetic stability in somatic cells of metazoa has become part of the trade-off between the allocation of scarce resources to either reproduction or somatic maintenance and is not expected to be maximized. While the concept of DNA damage as a main driver of aging is intuitively attractive, evolutionary logic dictates that other causes of aging would emerge over evolutionary time. Indeed, it is likely that age-related deterioration and functional decline is synchronized across different organismal functions. This would imply that given a molecular machinery of limited endurance, all bodily functions would adapt, and under such conditions a variety of harmful physiological late-life effects can be expected to develop.

Acknowledgments

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See also: Cell Death; Cellular Aging: Growth Factors and Cellular Senescence; Mitochondria and Aging.

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Driving Behavior

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Glossary

Certified Driving Rehabilitation Specialist (CDRS) – A certified specialist, most often an occupational therapist, physical therapist, or driver education instructor, trained to provide driver assessment and rehabilitation services to persons with disabilities or functional impairments that may affect their ability to safely operate a motor vehicle.

Mobility – The ability to get from one place to another, whether inside the home (in-home mobility) or outside the home (out-of-home mobility).

National Household Travel Survey (formerly Nationwide Personal Transportation Survey) – A national survey of a representative sample of US households to collect data on the frequency, purpose, and mode of personal transportation, as well as other information on users of the transportation system. The survey is conducted by the US Department of Transportation Federal Highway Administration approximately every 5–7 years.

Transit/Public Transportation – Transportation by bus, rail, or other conveyance, either publicly or privately owned, providing general or special service to the general public on a regular and continuing basis. Excludes school buses or charter or sightseeing service.

Introduction

Driving, and the ability to travel outside the home, is an important component of independent daily living. More so than in any other developed nation, Americans are highly dependent on personal automobiles for getting places. This is as true for older adults as it is for young and middle-aged adults. Compared to the overall US population, the population of licensed drivers is aging at an even faster rate, especially with respect to women. While older adults are generally safe drivers based on crash rates per licensed driver, they have higher crash rates per mile traveled, and they are much more likely to die in their crashes. Declines in vision, cognition, and physical function can make older adults less safe drivers, and many older adults will outlive their ability to drive. Improvements to the driver, the roadway, and the

vehicle can all help to keep older adults driving safely longer. When stopping driving is inevitable, improved transportation options can enable older adults to retain mobility and independence and remain engaged in their communities.

Importance of Driving

People today are highly dependent on personal automobiles for travel outside their home. The National Household Travel Survey shows that nine out of ten trips people make are in cars. Most of the remaining are walking trips, while less than 2% involve the use of public transportation.

Older adults are as dependent on personal automobiles as younger age cohorts. With increasing age, however, they are less likely to be drivers and more likely to be passengers in vehicles (see **Figure 1**). Still, persons age 65 or older drive themselves for two-thirds of the trips they take, and even those 85 or older are drivers for over half of their trips.

Like the US population as a whole, older adults tend to live in places where distances to needed services and destinations are great and where alternative means of transportation are not available. In the United States, half of all older adults live in the suburbs, and over a fourth live in rural areas outside of suburbs. In such locations, driving is often the only option for getting to the grocery store, going to see a doctor, or visiting friends. Driving also allows older adults the option of continuing to work or participate in volunteer activities. The preference of most older adults to age in place has contributed to a rapid graying of the suburban population over the past decade and reinforces the importance of retaining a driver's license for as long as possible.

Driving has both practical and symbolic importance to older adults. Even when alternative transportation is available, most older adults are reluctant to surrender their license to drive. This is true even if a spouse is available for driving. For many older adults who have grown up with the automobile, the ability to drive, and having a driver's license in their billfold or purse, is closely tied to their sense of independence and autonomy. Driving is also the most convenient, flexible, and accessible means of meeting one's transportation needs. Studies have shown that compared to drivers, non-drivers make significantly fewer trips and are less likely to engage in activities outside the home.

According to the most recent National Household Travel Survey estimates, men, on average, drive just under 10 200 miles per year, while women drive 4800 miles per year. Both numbers have increased over the past two decades, but the increase has been greatest for men.

Changing Driver Demographics

The US population is aging, but the population of licensed drivers has been aging at an even faster pace. This is primarily because more women drive today than in the past. During the early and mid-1900s, it was quite common for women not to drive, so that today's cohort of older drivers excludes many women who never learned to drive and who never obtained a driver's license. In contrast, driving is almost universal among women today, so that future cohorts of older drivers are likely to include many more women. Adults age 65 or older currently constitute just under 13% of the overall US population and a slightly higher proportion of its licensed drivers. Over the

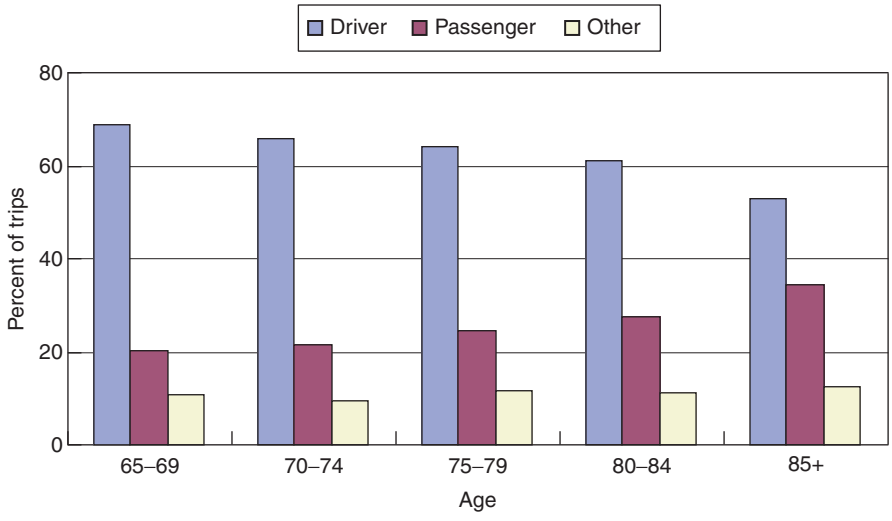

Figure 1 Travel mode of adults ages 65 and older. (From 2001 National Household Travel Survey data.)

next two decades, the proportion of licensed drivers aged 65+ is projected to swell to one in five.

Even though older women outnumber older men by a ratio of 3:2, women's and men's representation in the current licensed driver population is almost equal, due to the fact that women are more likely than men to stop driving. Although this may be less true of future cohorts of older women drivers, it is unlikely that the difference will be erased. **Figure 2** shows the percentage of men and women licensed within different age groups.

Older adults are less diverse racially and ethnically than the overall population, and licensed older adults are even less diverse. As minority populations age, it is anticipated that their share of the overall population over age 65 will grow, increasing from roughly 16% today to an estimated 27% by 2030. Just how this trend will manifest itself in the population of licensed older drivers is uncertain. Hispanic and Asian women, for example, are less likely than non-Hispanic White women to have a driver's license, a countertrend to the increase in licensure rates among older women. In addition, both minority men and women may have very different travel patterns and needs than the current cohort of predominantly non-Hispanic White older drivers.

Safety of Older Drivers

Motor vehicle crashes are the leading cause of injury death for persons ages 1–64; for adults age 65 or older, they are the second leading cause of injury death, behind falls. Based on number of crashes per licensed driver, older adults are among the safest drivers on the roadway. This is primarily because they drive many fewer miles than other drivers, and also because they tend to drive under safer conditions, e.g., during daylight hours and when traffic is less congested.

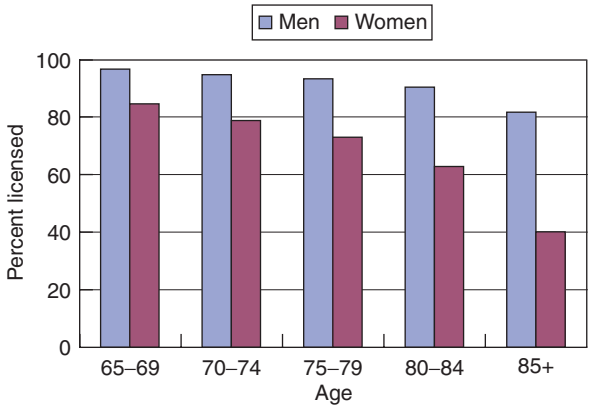

Figure 2 Percent of population licensed, by age and gender. (From US Department of Transportation, Federal Highway Administration, Traffic Statistics 2003, Table DL-20.)

When based upon number of miles driven, older drivers do exhibit higher crash rates, especially after age 75. This increase is largely attributed to age-related declines in functional capabilities important for safe driving. However, lower annual mileages and the fact that much of this mileage is accumulated on urban and suburban roadways are both likely to contribute to higher per mile crash rates.

The greatest concern, however, arises when one examines fatalities associated with involvement in a crash. Due to increased fragility that accompanies aging, older adults are much more likely to die as a result of a crash. This increased risk of dying in crashes of similar magnitude is apparent in crash data in adults as young as age 60 and increases steeply with age. As a result, both fatal crash involvements per licensed driver and fatal crashes per mile traveled are significantly higher for older drivers, especially those past the age of 75.

Figure 3 shows population-based motor vehicle crash deaths, differentiated by age and gender. Despite the fact that older adults are less likely than others to be involved in a crash, they are more likely to die from a crash. Population-based fatality rates are higher for men than for women, primarily because of the higher licensure rate among men, coupled with their higher annual mileages. The latter is especially true for the older adult population.

Along with their greater risk of dying in crashes, older drivers are also more likely to require admission to a hospital, to have longer hospital stays, and to experience more long-term disability, compared to younger drivers in crashes. However, older drivers are less likely than younger drivers to injure others in their crashes, including pedestrians. When older drivers crash, it is most often themselves who are injured.

The types of crashes in which older drivers are involved differ from those of younger drivers. Older drivers are more likely to crash at intersection locations and are especially overrepresented in crashes at signalized intersections when making a left-hand turn. They are also more likely than younger drivers to crash when entering or crossing a roadway at a stop sign location. Whereas younger drivers are more likely to be cited for speeding and following too closely, older drivers are more likely to be cited for failure to yield and disobeying a traffic signal.

Driving exposure likely plays a role in determining the crash patterns of older drivers. That is, because older adults accumulate a greater proportion of their driving time and miles in in-town and residential locations, one would expect a higher proportion of

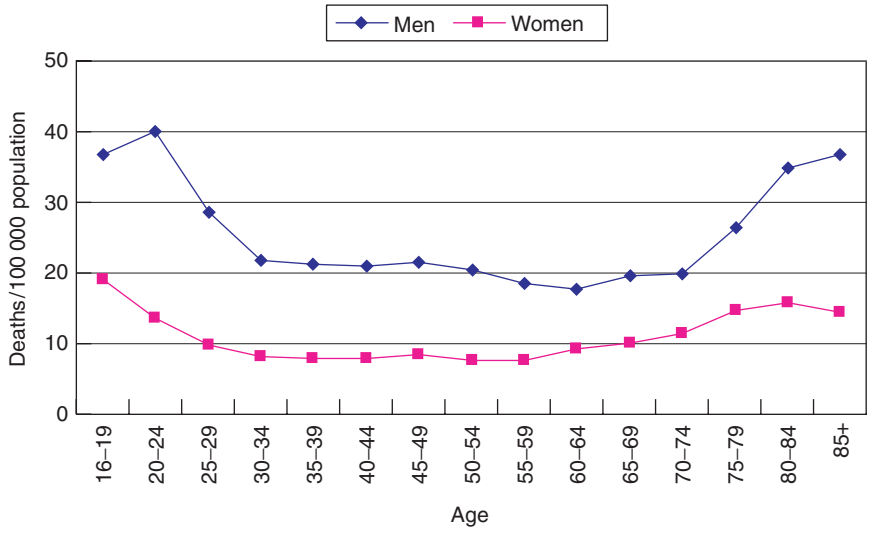

Figure 3 Motor vehicle crash deaths per 100 000 people by age and gender. (From Insurance Institute for Highway Safety, 2004.)

intersection collisions. However, declining functional abilities also increase older adults' risk of crashing. Problems in distinguishing target vehicles from surrounding clutter, judging closing speeds of approaching vehicles, attending to multiple events simultaneously, and quickly accelerating into traffic can all contribute to an increase in crash risk, especially when negotiating intersections.

In 2004, 15% of all persons killed in traffic crashes were age 65 or older. Taking into account projected increases in the older population, in the percentage of older adults (especially women) who are licensed, and in number of miles driven by both men and women, it has been estimated that by the year 2030 as many as one in four traffic fatalities will involve an older adult.

Age-Related Changes Affecting Driver Performance

Driving is a complex task, requiring the integration of a broad range of sensory, cognitive, and motor abilities. As people age, they are more likely to experience a variety of functional declines that can affect their ability to operate a motor vehicle safely. They are also more likely to have medical conditions and to take medications that can adversely affect driving performance. These changes contribute to their higher crash risks, as well as to a greater likelihood that they will be at fault in their crash.

Age-related changes in vision that can adversely affect driving performance include reduced visual acuity (both static and dynamic), decreased contrast sensitivity, reduced peripheral vision or other visual field losses, increased sensitivity to and poorer recovery from glare, decreased depth perception, and poor scotopic visual acuity or ability to see at night. Cataracts, macular degeneration, glaucoma, and diabetic retinopathy contribute to vision loss, and all are more prevalent in older populations.

Age-related changes in perception and cognition that have been linked to driving safety include attentional deficits (especially the ability to divide attention between two or more competing tasks), slower information processing and decision making, longer reaction times, poorer visuospatial skills, memory loss, and reduced judgment and decision-making abilities. For example, a person with impaired divided attention capabilities may be unable to attend to oncoming traffic, a pedestrian in the crosswalk, and the traffic signal when trying to negotiate a left turn at an intersection. Someone with poor visual search capabilities may not scan the driving environment to recognize potential driving hazards in time to react. Drivers must have knowledge of the rules of the road (e.g., which side of the road to drive on) and remember how to get to their destinations.

Alzheimer's disease and other progressive dementias are a particular concern for the older driver, since they inevitably imply a need to stop driving. Even in its early stages, dementia has been associated with an increase in crash risk. The question then becomes one of how much increased risk is too much. Since the patient's judgment is compromised, this decision often must be made by family members and other caregivers.

A final category of age-related changes that can affect driving safety relates to motor ability. Included in this category are muscle strength (e.g., the ability to apply brakes sharply and to grasp the steering

wheel), joint flexibility (e.g., the ability to turn the neck and look over the shoulder to check for oncoming traffic when merging into traffic), and general mobility (e.g., the ability to enter and exit the car). Arthritis can significantly compromise motor ability, as can Parkinson's disease and other neuromuscular disorders.

Driving ability can also be compromised by the medications used to treat conditions. Although this is true for persons of any age, it is especially important when considering the older driver, since older adults take many more medications, on average, than the rest of the population. Common medications that can raise red flags for older drivers include antidepressants, antihistamines, antihypertensives, antiparkinsonians, antipsychotics, benzodiazepines and other sedatives/anxiolytics, muscle relaxants, narcotic analgesics, and stimulants, including alcohol. Research has shown that the first few weeks of taking a newly prescribed medication can be an especially high-risk period for driving.

When evaluating an individual's fitness to drive, it is important that emphasis be placed on that person's actual functional abilities and likely prognosis, rather than on age or disease diagnosis per se. In driving, as with other areas of function, older adults exhibit tremendous individual variation.

Improving Safety for Older Drivers

Older drivers voluntarily engage in many practices that improve their driver performance and safety. They drive fewer miles, refrain from driving at nighttime or in heavy traffic, and drive in familiar areas and on familiar roadways. They also are less likely than others on the road to speed or to drive after consuming alcohol or drugs (except for prescribed medications). Older adults have the highest rates of seat belt usage, and they are less likely to engage in potentially distracting activities such as talking on cell phones or eating and drinking while driving. All of these practices help older adults remain safe behind the wheel.

In recent years, a variety of programs and initiatives have been undertaken to further assist older adults in continuing to drive as long as they safely can. For example, the American Medical Association collaborated with the National Highway Traffic Safety Administration to develop a guide to assist physicians in assessing a patient's fitness to drive and providing guidance for addressing identified problems. Some state driver licensing agencies have implemented increased driver screening at license renewals or have changed their driver license renewal policies pertaining to older adults. For example, states may require more frequent renewals for drivers past a certain age, require older adults to renew their licenses in person, or require that they pass certain vision tests or take a behind-the-wheel driving test.

For drivers facing medical problems and/or functional losses that can impair driving performance, certified driving rehabilitation specialists or other specially trained professionals can work with them to maximize their safe driving potential. This would typically involve a thorough clinical evaluation to identify the extent of functional loss, followed by a behind-the-wheel driving assessment. When warranted, driver rehabilitation services may be offered to help remediate or compensate for identified losses. For example, the driving rehabilitation specialist may recommend adaptive vehicle equipment or may work with the driver to improve certain driving techniques or skills. Interactive driving simulators are another option for helping older adults develop safe driving practices.

Improving driver performance is one way to help older adults remain safe on the road. However, it is just one part of a comprehensive approach to enhancing older driver safety and mobility. Equally important is improving the roadway and driving environment to better accommodate the special needs of older adults. Roadway improvements have the added benefit of increasing safety for all drivers, including those whose alertness may be temporarily impaired by drowsiness, distraction, or the consumption of medications, alcohol, or other drugs.

During the time that many of our nation's roadways were being built and standards were being set for everything from pavement markings to road signage to street lighting, there were very few older drivers, so that the 'design driver' was someone much younger. Today, however, it is becoming increasingly important to design our streets and highways with a much older population in mind. New standards and guidelines have been published specifically to address the needs of an aging population. Wider and brighter lane lines, more overhead street lighting, advance street name signs, larger and brighter signs, and protected left turn signals (left turn arrows) are just a few examples of roadway changes that can make it easier and safer for older adults to continue driving. In addition to benefiting older drivers, these changes should improve safety for all drivers, including drivers of any age with functional limitations as well as those who may be temporarily impaired by drowsiness, alcohol, or even the distraction of a cell phone conversation.

A final area of focus for improving safety for older drivers is the vehicle itself. Due to their increased fragility, older adults are particularly likely to benefit

from design changes to improve vehicle crashworthiness. Safety belts and front and side airbags help to protect older adults from injury and death when involved in a crash – even more so than for younger drivers. In the future, cars are likely to have safety belts with mechanical force limiters that keep the belt force from exceeding a predetermined threshold, thus avoiding some of the chest injuries encountered by some older drivers involved in crashes. There may also be smarter air bags that automatically adjust to inflate with less force for smaller and more fragile bodies.

Technologies such as in-vehicle communication systems can automatically notify emergency services in the event of a crash or other medical emergency, getting needed medical attention to the scene more quickly. Future cars may also come equipped with collision avoidance systems that will automatically sound an alarm or stop the car if approaching another vehicle too closely or quickly.

Many adults are already benefiting from adaptive equipment installed in their vehicles. Some examples include a knob attached to the steering wheel to make gripping and turning the wheel easier, pedal extensions so that a shorter person does not have to sit so close to the steering wheel, and seats that swivel to make it easier for someone to enter and exit the vehicle. Although these are all relatively simple interventions, they can make driving safer, easier, and more enjoyable for some older adults.

In summary, improving safety for older road users is best accomplished through a comprehensive program that simultaneously addresses the driver, the roadway, and the vehicle. Although significant progress has been made in all three areas, much remains to be accomplished.

Driving Cessation

Given the important role that personal automobiles continue to play in meeting transportation needs as people age, it is not surprising that stopping driving and surrendering one's license can have significant negative consequences. These consequences primarily affect older adults themselves, but can also extend to family members and other caregivers, as well as to the larger society. There are many factors affecting both the decision to stop driving and the consequences of stopping. In addition, stopping driving is not always an all or nothing situation: for many older adults, it is a gradual process, and for some it can involve intermixed periods of driving and non-driving. All of this makes driving cessation a difficult topic to study.

Age and gender are both significantly associated with stopping driving: as people age, they are less likely to drive, and older women are much more likely to stop driving than older men. These results were reflected in **Figure 1**, showing trip mode by driver age and gender. Declining health has also been linked to driving cessation. However, while certain medical conditions such as arthritis, Parkinson's, and stroke or heart attack may cause some older adults to give up driving, many others continue to drive, and poor health can sometimes even encourage driving if it makes it more difficult for people to walk or to access alternative forms of transportation.

In general, problems with vision (cataract, macular degeneration) and neurological disorders are most strongly linked to driving cessation. Women are more likely than men to stop driving for non-health reasons, including a general lack of confidence in their driving and a greater willingness to rely on others (including husbands) for getting places. For both men and women, socioeconomic factors can also play an important role, as can a ready access to alternative forms of transportation.

For many older adults, driving cessation is a gradual process, brought about at least in part by a reduced need or desire to go places. However, reduced trips outside the home are also an important consequence of driving cessation. Studies have consistently shown that non-drivers are much less likely than drivers to travel outside the home, especially for non-essential trips such as visiting friends, attending religious services, or participating in volunteer activities. Often it is difficult to distinguish those who have reduced driving because they have less need or desire to go places from those who go fewer places because they are unable or unwilling to drive.

This blurring of cause and effect is also true for other adverse outcomes linked to driving cessation. A very important question that many have tried to answer is whether driving cessation contributes, either directly or indirectly, to a decline in functional status and health. For some older adults, giving up driving leads to social isolation and increased depression symptoms. Former drivers may experience a loss of independence, a drop in self-esteem, and decreased life satisfaction. This is true even if alternative transportation (e.g., a spouse still drives) is available, and regardless of the reason for stopping driving. The end result can be a downward spiral of negative events that ultimately leaves the individual in a poorer state of health.

Fortunately, most individuals do adjust to giving up the keys, even if they are not entirely happy with their situation. Much depends on the extent to which they remain in control and are able to continue to

meet their transportation needs, whether this be through rides from family members or friends, use of public transit and/or paratransit, or, depending upon their health, walking or bicycling.

Driving Alternatives

An estimated one in five American adults age 65 or older does not drive. This number includes many former drivers who have outlived their ability to drive. Women are especially likely to outlive their ability to drive, since they both live longer and stop driving earlier than men. For men and women, the need to travel does not stop when they stop driving; they still need to go to the grocery store, to the pharmacy, and to their doctor, and they still enjoy visiting with friends and participating in a variety of activities outside their homes. A growing number also hold jobs and require transportation to continue working or volunteering.

To meet their travel needs, older non-driving adults most often rely on family members and friends to drive them places. However, a range of transportation options is needed to ensure that all older adults are able to access the goods and services they require and can continue to live full and active lives. In addition to traditional fixed route buses, older adults benefit from flexible route buses, paratransit services, public dial-a-ride systems, taxis, and specialized medical and other transportation services for seniors. These options vary in the level of support services they provide, e.g., whether the individual is picked up at a bus stop, in front of the home, or escorted from the home. They also vary greatly in terms of cost, both to the individual and to the provider. Because older adults differ in their functional capabilities, their living situations, and their experiences and preferences, there is no one-size-fits-all transportation solution.

A growing number of communities offer supplemental transportation programs for older and disabled adults. These programs are intended to complement existing public transit and paratransit services, serving older and/or disabled adults who are no longer able to walk to a bus stop, need help getting into or out of a van, cannot afford taxis, or simply want to go places they cannot get to on a bus. Most of these programs are run by non-profit organizations (churches, hospitals, senior centers, agencies on aging, volunteer groups, etc.), and many target rural and suburban areas not normally serviced by transit. Typically, they are funded by a combination of grants and fees or donations from riders, and often they are able to provide rides at no cost or for a small flat rate fee. Perhaps most importantly, they are able to provide senior-friendly service, escorting seniors to and from their homes, transporting them in vans or autos that are often driven by senior volunteers themselves, and generally mimicking the comfort, convenience, and flexibility of traveling in one's own car.

Currently less than 2% of all trips taken by older adults involve public transit, in part because bus and other transit services typically are not available in the suburbs and rural areas where older people live, but also because transit does not adequately serve the special needs of older persons. Bus service in particular could be made more attractive to seniors if it provided some of the amenities of private transportation programs such as more flexible routing, drivers trained in assisting older adults, and service to destinations frequented by seniors. Buses themselves can be made more accessible to seniors, for example, by having wider and lower entries.

Next to riding in cars, the greatest number of trips taken by older adults are shorter trips made on foot. Walking, however, can be a dangerous activity for older adults: although they comprise 13% of the population, over 20% of pedestrian fatalities in 2003 were adults age 65 or older. Wider sidewalks, improved street lighting, pedestrian signals that accommodate an older person's slower walking speed, and benches that allow for stopping and resting are just a few of the amenities that contribute to a safer and more attractive walking environment for older adults.

Beyond safe and attractive places for walking, it is also important that destinations (shops, grocery stores, churches, etc.) be located close to residential areas where older people live. This, in turn, requires that communities adopt mixed-use zoning and other planning practices conducive to shorter trip distances. It also requires that people plan ahead for the possibility of not driving, choosing to live in places where they will be able to remain mobile even if they can no longer drive. Doing so greatly facilitates an older person's ability to age in place.

Both transportation choices and walkable communities are vital components of a recent movement to create more livable communities. Such environments allow older adults to remain independent and engaged in their community while aging in place. However, their benefits extend to community residents of all ages.

Future Directions

Given the projected increase in the number of older drivers and the importance of driving for maintaining mobility and quality of life, future research and

programmatic efforts should focus on improving safety for older road users as well as on providing viable alternatives to driving for meeting everyday transportation needs. A comprehensive approach to improving safety that addresses the driver, the roadway, and the vehicle is required. With respect to the driver, further research is needed to identify functional abilities important for the safe operation of motor vehicles, ways to assess these abilities in the broader population, and approaches for assisting drivers in compensating for identified losses. When remediation is not an option, as may be the case with dementia and other cognitive disorders, research is needed on how best to assist older adults in transitioning from driving to alternative forms of transportation.

With respect to the roadway, much work has already been done in identifying improvements that should benefit older road users. The main challenge here lies in evaluating the effectiveness of the recommended changes and encouraging state and local transportation departments to incorporate the changes into their highway maintenance and traffic operation programs.

As is the case with roadways, vehicle design has only fairly recently begun to take into account the special needs of older drivers. As new designs and technologies are considered, it will be important to include older adults in the development process. In addition, older adults should be educated about those vehicle features that are most important to their safety as drivers and car occupants.

Continued research is also needed to elucidate the importance of driving to the health and well-being of older adults, actions older adults can take to extend their safe driving years, and ways to minimize the negative consequences of driving cessation. An important area of research and program development is how to provide an alternative to driving that is acceptable to older adults but that does not unduly burden society. It is likely that a combination of alternatives will be needed with support from both the public and private sectors.

The preceding represent only some of the areas in which continued research and programmatic activities are needed to enable older adults to continue to drive as late in life as possible and to access alternative transportation when driving is no longer an option. Given the importance of driving to older adults and the increased risks faced by older drivers, there is obviously considerable work to be accomplished in preparation for a rapidly aging driving population.

See also: Demography; Vision.

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E

Economics: Society

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Glossary

Snitching a Sandwich – Restructuring institutions or incentives to make the system work more smoothly than it did before.

Mandatory Spending – Spending not directly controlled through the annual appropriations process.

Discretionary Spending – Spending resulting from annual congressional acts of appropriation.

Entitlement Programs – Federal programs providing benefits to individuals, businesses or units of government that apply for payments and meet eligibility requirements established by law.

Introduction

The expansion and contraction of social programs for older people and for the population in general occur historically. Changes in direction have often been ascribed to political and ideological movements, but the powerful role of economics in creating, expanding, or contracting social programs must also be considered.

When the direction of public policies changes, it is often ascribed to changes in ideology or politics. Of course, ideology and politics do play a part, but frequently lost in this consideration is the powerful role of economics in creating, expanding, or contracting social programs. The primary insight that economics has to offer is often summed up in the phrase 'there is no such thing as a free lunch.' This insight, often presented as a law of economics, permeates all policy issues; it is a law that individuals and societies do their best to hide from or at least to avoid facing. But they cannot.

Luckily, the law has an ancillary that lessens the force of the law and allows public policy to work: 'once in a while you can snitch a sandwich.' It may be said that this ancillary is the foundation of public policy, and good public policy essentially means snitching sandwiches.

'Snitching a sandwich' involves restructuring institutions or incentives to make the system work more smoothly than it did before. For example, paying tolls only one way on bridges where the majority of people return over a connected toll bridge makes traffic flow better. Integrating road pricing for certain highly congested roads, as was done in London, yields a similar net gain. Instituting tradable permits for pollution reduction, as in the Kyoto Accord, is another example. The list goes on. All of these programs offer some gains and some costs, but by almost all observers' accounts, the gains exceed the costs.

Unfortunately, government programs are not often sold as sandwich snatching, but instead are sold as free lunches, which promises too much. Social programs are often presented or justified by hiding the costs and/or overselling the benefits. Some would argue that this has been the case with the United States government's role in providing economic security for the elderly. This policy is indeed an example of a snitched sandwich, but because it was presented as a free lunch, it will pose serious problems for the government in coming decades.

The reason for the problem is the interaction of economic growth and entitlement provision. When an economy is growing quickly, future entitlements can be provided out of that growth. When the economy is growing more slowly, it is more difficult to provide for those entitlements; demand outruns supply, which aggravates the problem of scarcity.

Scarcity, with all of its social, political, and economic consequences and implications, is such a persuasive concept in the social sciences and social philosophy that it has been frequently taken for granted or treated as an assumption. Although the competition for, and distribution of, material and human resources obviously influence human behavior and public policies, the notion of scarcity as such is often ignored during discussions of public policy

changes. Frequently, suggestions about policies have been branded as 'political.'

While the political and legal forces in society do indeed influence the types of human behavior and the directions of public policies, over the coming decades economic factors will likely predominate due to pressure placed on the fiscal capacity of the government. Politics may be the vehicle for change in policies, but the underlying fiscal capacity of government drives politics and policies, dictating whether legislators support a program's expansion or its contraction. In short, political moves and changes in public policies in one direction or another are heavily influenced by economic consideration and are tempered by social and political philosophies.

Social Programs to Help the Elderly

It is difficult to see someone suffer when others have plenty. Civilized societies deplore that scenario and establish programs to lessen that suffering. That is the underlying basis of many government programs that provide economic security for the elderly; it makes good policy sense, which is why the Social Security program is strongly supported by a large majority of the population. Most social programs have been positive additions to society by most people's standards; they are examples of snitching sandwiches, which is what good public policy is all about. But they are not free lunches. Because they are presented as free lunches, without cost, the snitched sandwich they actually provide is much smaller than it could be. The problem is that the programs have been oversold on the benefits, and costs have been hidden or pushed aside, to be faced later, which leads to decisions about programs being made without the appropriate balancing of revenues and outlays.

The central problem with government programs for the elderly is that entitlements have been emphasized but costs have been downplayed and pushed aside. Initially, when these programs were established, many people were paying in but there were few recipients, resulting in the government appearing more generous than it would have had the costs been faced directly. The programs were sold to society by creating a sense of future entitlements among the population without fully accounting for the costs of those entitlements.

The created entitlements were both implicit and explicit. The explicit entitlements sometimes, but not always, showed up on the government budget; the implicit ones did not show up on the budget, but they were entitlements just the same. The problem is a 'real' problem, not a 'financial' one. Trust funds, or individual investment accounts, will not solve the problem unless they either include a way to get a larger percentage of real resources from workers in the future or reduce the benefits that are promised for the future. Most political discourse shies away from discussing the degree to which the entitlements will have to be cut, or how greater resources will have to be gathered to meet promised entitlements. Ideally, these programs would have been structured as 'steady state sustainable' – that is, structured so that steady state expenditures and revenues would be neutral in response to changing economic and demographic conditions over time. Steady state sustainability should be a central consideration of policies, and embedding that consideration in the design of the system will lead to a better balancing of obligations to pay the entitlements and the ability to pay them.

Because social programs have been designed without many, if any, built-in adjustment mechanisms, the programs have been expanded too much in good times and will have to be cut in bad times. Political considerations will push aside facing these problems until they are at crisis levels and must be faced. For example, in the mid-1990s there was a move to face these problems; at that time both the Republican-dominated Congress and the Democratic President advocated cuts in Medicare and Medicaid due to the slowing economy and the declining fiscal capacity of government. However, in the late 1990s economic growth increased, and the willingness of either side to consider the issues started to wane.

In 2001 economic growth slowed, but by then the political will was lost. Instead of facing up to the difficult issues, both sides essentially pushed them aside, and jointly expanded the Medicare program to include prescription drug benefits, enacted in 2003, even as the forecasted trillions of dollars of surplus metamorphosed into large projected budget deficits, making it even more difficult to deal with the future imbalance between expected entitlements and expected responsibilities to pay for those entitlements, responsibilities captured in the concept of fiscal capacity of the government.

Fiscal Capacity of the Government

Fiscal Capacity in the 1960s

During the 25 years between 1940 and 1965, both the young-age and old-age dependency ratios were rising. Whereas the young-age dependency ratio increased from 0.582 (i.e., 582 persons under the age of 20 per 1000 persons between the ages of 20 and 64) in 1940, to 0.764 in 1965, the old-age dependency ratio rose from 0.116 (i.e., 116 persons age 65 or over per 1000 persons between the ages of 20 and 64) in 1940 to 0.182 in 1965. As a consequence, the

total dependency ratios increased from 0.698 in 1940 to 0.946 in 1965 (see Appendix A).

The concurrent increase in old-age and young-age dependency ratios implied substantial need for social programs for both young and old dependants. In the 1960s, when the demand for resources for social programs was rising, the fiscal capacity of the federal government was able to accommodate the needs. By the time the recession of 1960–61 ended in early 1961, there was an unprecedented, continuous expansion of the economy through the end of 1969. Therefore, it was no accident that the Great Society programs, such as antipoverty measures, Medicare, and Medicaid, came into existence by the mid-1960s.

Fiscal Capacity since the 1970s

The federal budget has been in continual deficit in all the years since 1969, except 1998 through 2001. In the 1970s, budget deficits averaged some $35 billion per year. In the 1980s, the average annual budget deficit reached a much higher level of approximately $150 billion. From 1990 through 1997, the average annual budget deficit was higher yet, at $190 billion (see **Table 1**). Under these fiscally restrictive circumstances, not only were new social programs virtually precluded from being enacted, but also existing programs were faced with cutbacks.

In the late 1990s, reversing the trend of some 30 years, budget deficits were replaced by surpluses as a result of tax and spending policies conducive to economic growth. Thus, from 1998 through 2001, budget surpluses averaged nearly $160 billion per year (see **Table 1**). This development was, however, short lived. Tax cuts, spending increases, and slower growth soon eliminated the surpluses and returned the government to large deficits, averaging some $315 billion a year from 2002 to 2004. These deficits are expected to continue into the foreseeable future. Short-term projections indicate that the estimated deficits for 2005 and 2006 will be more than $400 billion per year (see **Table 1**).

Table 1 Budget deficit or surplus, 1970–2006 (in billions of U.S. dollars)

Year	*Annual deficit*	*Year*	*Annual deficit*
1970	−2.8	1989	−152.5
1971	−23.0	1990	−221.4
1972	−23.4	1991	−269.2
1973	−14.9	1992	−290.4
1974	−6.1	1993	−255.1
1975	−53.2	1994	−203.2
1976	−73.7	1995	−164.0
1977	−53.7	1996	−107.5
1978	−59.2	1997	−21.9
1979	−40.7	1998	+69.2
1980	−73.8	1999	+125.5
1981	−79.0	2000	+236.2
1982	−128.0	2001	+128.2
1983	−207.8	2002	−157.8
1984	−185.4	2003	−377.6
1985	−212.3	2004	−412.1
1986	−221.2	2005[a]	−426.6
1987	−149.8	2006[a]	−390.1
1988	−155.2		

Source: Economic Report of the President, 2005, p. 303.
[a] Estimated.

Balancing the Budget

Public opinion polls show that, in the abstract, 80% of Americans favor balancing the budget. However, that percentage falls precipitously if budget balancing means cuts in Social Security or Medicare, or increases in taxes.

Strong economic arguments can be made for moving toward a balanced budget. A major reason to lower the deficit is to increase national savings, which in turn increases national investment in physical and human capital, which in turn increases productivity growth and raises the standard of living. A second reason is for the government to retain significant borrowing capacity for emergencies. But the real issue is not balancing the budget, but rather balancing entitlements, including implicit ones, with responsibilities to pay for them. Budgets do not necessarily capture this larger sense of balance (and are often designed or manipulated to hide that larger sense of balance) and thus can be misleading.

Although balancing entitlements may be a wise course, specifying how it should be done is another matter. In the political climate of the early twenty-first century, military expenditures cannot be cut and taxes cannot be raised. This puts almost all the pressure of entitlement reductions on Medicare and Medicaid because as of 2005, they comprise one-third of the spending of the 10 largest entitlement programs and are projected to assume greater importance in future years. However, the need to balance entitlements comes at a time when health-care programs for the economic security of older people are becoming ever more important (see Appendix B).

Entitlement Programs and the Budget

Federal outlays may be divided into two categories: mandatory and discretionary. Mandatory spending refers to spending not directly controlled through the annual appropriations process. Discretionary spending, on the other hand, results from annual congressional acts of appropriation.

The bulk of mandatory spending consists of entitlement programs – federal programs providing

Table 2 The 10 largest entitlement programs in the United States, 2002

Program	*Entitlement spending (%)*
Social Security	37.8
Medicare	21.2
Medicaid (federal share)	12.3
Federal civilian retirement and disability	4.7
Unemployment compensation	4.2
Military retirement	2.9
Earned income and child tax credit	2.7
Supplemental Security Income (SSI)	2.6
Family support payments (federal share)	2.1
Veteran's benefits	2.1
Total	**92.7**

benefits to individuals, businesses, or units of government that apply for payments and meet the eligibility requirements established by law. Nonentitlement forms of mandatory spending include net interest on the national debt and deposit insurance.

The federal budget contains over 400 entitlements and other mandatory spending accounts. The largest 10 programs, listed in **Table 2**, accounted for nearly 93% of entitlement spending in fiscal year 2002.

Federal entitlement spending has been rising significantly faster than the overall economy. Some believe that explosive growth in entitlement programs is a very recent phenomenon, but entitlement growth was actually most pronounced from 1967 to 1976, when Medicare and Medicaid began and grew, the food stamp program became a national program, the Supplemental Security Income (SSI) program was established, and major increases in Social Security benefits (the most prominent of which was the cost-of-living adjustment) went into effect.

Social Security, Medicare, and Medicaid account for more than 70% of the 10 largest entitlement programs listed in **Table 2**. From 1993 to 2003, the annual rates of growth in Social Security outlays averaged 4.5% of the gross domestic product (GDP), according to the Congressional Budget Office (2005). This rate is projected to rise to 5.6% per year during 2005 through 2015. In contrast, Medicare and Medicaid will become greater financial issues. While the annual growth rates averaged 6.7% for Medicare from 1993 to 2003, the program is projected to grow at 9% a year from 2005 to 2015. For Medicaid, the average annual rate of growth was 7.8% during the years from 1993 to 2003, and the same rate of annual growth is projected for this program from 2005 to 2015.

By comparison, the consumer price index (CPI) grew at an annual rate of 2.5% from 1993 to 2003, and it is projected to rise only 2.2% annually from 2005 to 2015. So all three entitlement programs have been growing and are projected to grow at rates much faster than general inflation.

Furthermore, the annual average rate of growth in the GDP from 1993 to 2003 was 5.1%, and this rate is projected to rise at a lower rate of 4.9% per year for the period 2005 to 2015. So, again, all three entitlement programs have been growing and are projected to grow at rates much higher than the rates at which the economy has grown and is expected to grow in the next decade.

These trends imply increasingly larger claims on the federal budget to meet the obligatory payments under these programs, which, in turn, implies greater influence of economic consideration on policy decision making.

Economics and Social Programs

The 'no free lunch' law is essentially an expression of the phenomenon of scarcity, the fundamental issue with which economics is wrestling. Economists start from the basic notion that our ability to satisfy human wants is limited. At any one time, an economy has only a limited command over the human and material resources with which to produce goods and services. On the other hand, human wants for goods and services seem limitless. Therefore, one of the central issues is how best to satisfy unlimited human wants with limited available resources.

Scarcity, as the basic fact of economic life, pervades all societies, regardless of their political orientation or levels of economic development. Societies simply do not have all the resources needed to produce all the goods and services their members want. This fundamental constraint is as true in a rich country as it is in a poor one; this same constraint exists in countries with different ideologies. Although scarcity always imposes the ultimate constraint, the condition is more acute in poor countries than in rich ones.

Because society does not have all the material and non-material resources with which to produce all the goods and services wanted, choices must be made. Economic reasoning leads one to recognize the trade-off: if one wants more of one thing, one must be prepared to have less of another thing, or a little less of everything. What one must give up in order to get something else is known as the opportunity-cost concept of cost.

The opportunity-cost concept applies to all aspects of life. It embodies economic forces, the forces of scarcity, as noted earlier. In order to allocate scarce resources and scarce commodities, some socially agreed-upon criteria must be established.

When a society allows economic forces to work through the market relatively freely, they are called

market forces. Market forces deal with scarcity of goods and services by means of their relative prices. Market forces have been captured in the symbolism of the 'invisible hand,' which is the price mechanism in which the rise and fall of prices guide people's decisions in buying and selling.

Societies cannot choose to allow economic forces to operate, because they are always operating. Societies can choose only whether to allow market forces to predominate. Other forces play a major role in deciding whether market forces will operate. Social and historical forces can prevent the invisible hand from working in an unfettered manner, and the way in which entitlements and the responsibilities to fund them play out will depend on how these social and historical forces interact with economic forces.

The Policy Challenge Ahead

Although most policy discussion in 2005 has focused on the Social Security program, Medicare and Medicaid programs will be under greater budgetary scrutiny over the coming decades. With advances in health care and growth in the older population, especially among the oldest-old (generally defined as those 85 or older), the medical needs of the elderly will be growing almost exponentially, in terms of both medicines and hospital care. Furthermore, long-term care for many of the elderly population needs to be provided. Will the needed resources be made available? Economics and the fiscal capacity of the government will be central in the debate. Society must decide whether it should increase the percentage of real resources it gets from workers or decrease the real resources it provides to the elderly, or some combination of these choices. Somehow, society must balance these choices by facing up to the 'no free lunch' law. Doing so will not be easy, but it is a policy challenge that society must face.

We suspect the options chosen will be some combination of tax increases and benefits decreases, and possibly some borrowing (which will solve the current problem, by pushing the responsibility issue off to the future). Economics does not dictate which of these solutions is the best; it simply says that some combination of them must be implemented. Our hope is that, in doing so, government snitches as many sandwiches as it can.

Appendix A: Dependency Ratios and Dependency Costs

Because the future financing of entitlement programs (relying on taxes from workers, typically younger persons, to pay benefits to recipients, typically older persons) depends considerably on the number of workers in relation to retirees, dependency ratios serve as useful approximate indices of costs. This section provides a discussion of dependency ratios and dependency costs. **Table 3** shows dependency ratios in the United States in selected years from 1940 through 2080.

The old-age dependency ratio is projected to rise in the future. Assuming a fertility rate of 1.9 (referring to the average number of children a woman gives birth to in her lifetime), this ratio will increase from

Table 3 Dependency ratios in the United States in selected years from 1940 to 2080

Year	*Old-age dependency ratio*[a]	*Young-age dependency ratio*[b]	*Total dependency ratio*[c]
1940[d]	0.116	0.582	0.698
1945[d]	0.124	0.557	0.681
1950	0.138	0.587	0.725
1955	0.157	0.657	0.814
1960	0.173	0.732	0.905
1965	0.182	0.765	0.947
1970	0.185	0.713	0.898
1975	0.190	0.638	0.828
1980	0.195	0.555	0.750
1985	0.201	0.505	0.706
1990	0.209	0.489	0.698
1995	0.213	0.495	0.708
2000	0.208	0.485	0.693
2005	0.203	0.464	0.667
2010	0.210	0.446	0.656
2015	0.235	0.437	0.672
2020	0.271	0.436	0.707
2025	0.313	0.439	0.752
2030	0.350	0.443	0.793
2035	0.368	0.441	0.809
2040	0.373	0.435	0.808
2045	0.376	0.430	0.806
2050	0.381	0.430	0.811
2055	0.389	0.430	0.819
2060	0.401	0.431	0.832
2065	0.409	0.430	0.839
2070	0.419	0.429	0.848
2075	0.425	0.428	0.853
2080	0.431	0.428	0.859

Sources: Board of Trustees (2005) *The 2005 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Disability Insurance Trust Funds*, p. 77. House Document 109-18, 109th Congress, 1st Session. Washington, D.C.: U.S. Government Printing Office.

[a] The number of persons aged 65 and over divided by the number of those aged 20–64.

[b] The number of persons under age 20 divided by the number of those aged 20–64.

[c] The sum of the number of persons aged 65 and over and the number of those under age 20, divided by the number of those aged 20–64.

[d] From special tabulations by the Office of the Actuary, courtesy of Felicite Bell and Stephen C. Goss, January 15, 1992.

0.214 in 1995 to 0.394 in 2060, or an 84% increase for the 75-year period. Such an increase implies an immense rise in the tax burden on the working population in order to finance public expenditures for the old.

However, in addition to increasing the old-age dependency ratio, low fertility rates will result in fewer young persons and thus in a declining young-age dependency ratio. This ratio is projected to decrease from 0.494 in 1995 to 0.417 in 2055, a decline of about 15.6%.

Because workers are called on to support both old and young dependants, the total dependency ratio suggests the total support burden on the working population. The total dependency ratio is projected to rise from 0.708 in 1995 to 0.811 in 2060, a 14.5% increase over the 75-year period. A rise or decline in the total dependency ratio tends to increase or decrease the total tax burden, but the extent of change depends on the relative costs of supporting the old versus the young and on the degree to which the old-age and young-age dependency ratios change. Moreover, the ability and willingness of the working population to bear such a burden are also important considerations.

The relative costs of supporting the old versus supporting the young are crucial factors in determining what effect the changing dependency ratios will have on society's support burden. The average cost of the old dependant is believed by some to be approximately three times that of the young dependant based on a study from the mid-1970s. It was estimated that $3701 was spent for each aged person under government programs compared to an estimated $1215 per young dependant. This three-to-one cost figure was arrived at for the old-age dependants by dividing the population over 64 into the estimated total government program expenditures for the old; for the young dependants, by dividing the population under 18 into the estimated total government program expenditures for this population.

That procedure for arriving at the average cost per dependant produces what should properly be called the 'per-assumed-dependant cost' in contrast to the 'per-actual-recipient cost.' The per-assumed-dependant cost is a definitional one, because all persons in a given age category are included in the figure that is divided into the program expenditures in the numerator. By contrast, the alternate method – per-actual-recipient cost – is a more appropriate measure, because it counts only those in the dependant age group who actually receive program expenditures. The assumed-dependant cost approach conceptually underestimates the support cost for the young who receive benefits under government programs, because relatively more young persons than old persons do not receive benefits, yet in the calculation all persons are included as if they were recipients. Moreover, the three-to-one cost relationship was based on estimates that define young dependants as being under age 18; they thus leave out most of the expenditures for higher education.

However, the per-actual-recipient cost is difficult to obtain for several reasons. Many government programs do not have published (or in some cases, even unpublished) data on age and other characteristics of recipients. Also, calculations of per recipient cost are more difficult because a number of persons are recipients of several government programs. In addition, in-kind programs such as public housing are not easy to measure. A lack of time-series data on recipient characteristics under various government programs poses yet another impediment to analyzing the historical development in dependency ratios and dependency costs.

As mentioned previously, the change in the tax burden resulting from the change in the total dependency ratio also depends upon the degree to which the old and young dependency ratios change. In the preceding discussion of the per-assumed-dependant cost as opposed to the per-actual-recipient cost, the old dependants were defined as the population over 64 and the young dependants as the population under 18. Obviously, if the old group is defined to begin at age 62 or 68, or the young category at age 20 or 22, the dependency ratios and the associated dependency costs will change.

As also mentioned, the ability and willingness of the working population to bear the support cost are important considerations. The ability of the working population to support dependants is influenced by such factors as the level of earnings, the labor force participation rates, and the unemployment rate, and these factors are in turn influenced by the level of productivity, the rate of economic growth, the state of demand, and the like. Furthermore, the overall financial ability of the working population to bear the support cost will be affected by private as well as public expenditures on behalf of the old and the young dependants.

Finally, the total support cost for all dependants would have to include dependants in the middle-age group in addition to the old and young dependants. Expenditures for middle-aged dependants include a number of government programs covering unemployment, disability, medical care, public assistance, and housing subsidies.

Appendix B: A Supply-and-Demand View of Economic Security

Economic well-being is generally discussed in reference to several different criteria, such as income, wealth, and consumption. Over the years, the gap has narrowed between the elderly and non-elderly insofar as income is concerned. Some conclude that the elderly have reached the same level of economic security as the non-elderly. However, even if the elderly have gained income parity with the non-elderly in terms of poverty rates, one may not thereby infer that their economic security levels are the same.

Economic security is a broader concept than income security. A person is concerned not only with the acquisition of income and assets, but also with their retention and disposal. It is well known, for example, that the elderly, when compared to the non-elderly, are at greater risk and must budget more for medical and personal care services despite Medicare and Medicaid. But potentially significant expenditures for health care are not generally given explicit consideration in assessments of the economic status of the elderly versus the non-elderly. A more accurate assessment of economic security, therefore, requires that current income, accumulated wealth, and consumption expenditures be considered from the standpoint of supply and demand. In that light, income and wealth represent the supply of resources, and consumption represents the demand on those resources.

Before arriving at the demand-and-supply view of economic security, we briefly discuss each of the three criteria, income, wealth, and consumption, that have been commonly used to assess economic well-being.

Income

The income status of the elderly has substantially improved in the last several decades, but income status often is discussed by reference to the incidence of poverty. In 1967, for example, the poverty rate among the elderly (age 65 +) was 30%, whereas the poverty rate among those aged 18–64 was 10%. Since then, those rates have converged; they stood at 10.2% for those 65 and over versus 10.8% among those 18 to 64 in 2003. In terms of per capita income, statistics show that the elderly have reached the relative standing of the non-elderly over several decades.

Wealth

Another criterion is ownership of accumulated wealth, or more precisely, net worth, which is the value of assets minus the value of liabilities. In terms of wealth, the elderly also fare well. Wealth holdings by persons 65 and older is the highest among all age groups except those between 55 and 64 years old. Some conclude, therefore, that the elderly are better off than the non-elderly, but a good deal of their net worth is in traditionally illiquid forms. Combining illiquid and liquid assets in order to measure economic capacity implies converting illiquid assets into readily spendable income. Home equity, for example, represents a significant part of net worth, but how meaningful is it to impute income from home equity?

Some see the increasing use of home equity lines of credit among middle-aged homeowners as a harbinger of their future comfort with reverse mortgages. But encumbered home equity in middle age is likely to reduce the equity that may be needed for retirement income. This is an important issue, because home equity can be a resource with which to finance consumption in old age. It is especially significant because home equity is increasingly seen as a viable resource to help finance future long-term care.

Consumption

The third criterion uses consumption expenditures to infer economic well-being. Neither income nor wealth is a good measure, some argue. They propose that consumption is a superior measure of economic well-being. For example, in 1986, the ratio of income between the affluent and the poor was 16 to 1. That is, a vast difference existed between the poor and the affluent: if a poor person had $1.00, the affluent person had $16.00. But in terms of per-consumer-unit spending, they would infer that life at the bottom of the American money-income distribution was only moderately less attractive than at the middle, and about half as attractive as at the top. According to per-consumer-unit spending, for every $1.00 spent by the poor, the middle class spent $1.29 and the affluent spent $2.31. Seen in terms of consumption, therefore, the difference between rich and poor was much narrower than in terms of income.

The difference between poor and rich was even smaller when considering consumer expenditures on the four essential necessities, food, shelter, apparel, and medical care. For every $1.00 spent by the poor on these necessities, the middle class spent $1.14 and the affluent spent $1.82. This view must not be taken lightly.

Of the five income distribution quintiles, only the top two showed an excess of incomes over expenditures. All three lower quintiles showed expenditures

over income; not all of the members of these quintiles may be expected to be dissavers (i.e., those disposing of accumulated savings). Perhaps the humorist Artemus Ward anticipated the consumption measure when he said, "Let us all be happy and live within our means, even if we have to borrow the money to do so." (Mardy Grothe (2004) *Oxymoronica: Paradoxical Wit and Wisdom from History's Greatest Wordsmiths*, p. 33. New York: Harper Collins). Consumption as a measure of economic well-being can be misleading.

How well-off are the elderly under this measure? The same data source, the Consumer Expenditures Survey for 1986 conducted by the Bureau of Labor Statistics, provided information for seven age groups. Per person spending on the four basics by the oldest two age groups (65–74 and 75+) was higher than that by all five younger groups. Were the elderly enjoying a higher measure of economic welfare than the non-elderly?

Per person spending on food, shelter, and apparel, with minor exceptions, was remarkably similar among all age groups. Health care, however, accounted for about 18% of the four basics for the 65–74 age group and more than 25% of the four basics for the 75+ group, compared with 9% for the 45–54 age group and less than 7% for all the younger age groups. That the elderly group spends more of its total budget on health care is not surprising. But the inference from using consumption as a measure is that if the elderly spend less on health care, their economic well-being would be lower. Conversely, the younger age groups can improve their economic well-being by spending more on health care. The irony is apparent.

Supply of and Demand for Resources

In summary, income, wealth, and consumption may be viewed from the standpoint of supply and demand. As stated earlier, income and wealth represent the supply of resources, and consumption represents demand on those resources. In order to measure economic well-being, therefore, income, wealth, and consumption should be included. Even if the elderly have achieved income and wealth levels on par with the non-elderly, it does not follow that their economic security is the same as younger groups, because older people are faced with an actual or potential higher demand on resources for health care, including long-term care.

Health-care expenditures represent what could be called a first claim on income. When the income and net worth of the elderly and non-elderly are equal, then the supply of resources is the same for both groups. After the first claim is deducted from these resources, however, an obvious disparity in resources results between the elderly and non-elderly groups.

It is difficult to exaggerate the importance of health care to older Americans. A Greek physician, Herophilus 335–280 B.C., (who is called the Father of Anatomy) said it well, "To lose one's health renders science null, art inglorious, strength effortless, wealth useless and eloquence powerless" (Massengill, 1943, p. 28).

See also: Health Care and Services; Medicare and Medicaid and Economic Policy of Health Care; Social Security.

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Education and Aging

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Glossary

Formal Learning – Education sponsored by the state or private institutions with parallel interests and goals directly related to societal needs, usually terminating in a degree or credential.

Informal Learning – The lifelong process by which individuals accumulate knowledge, skills, attitudes, and insights from daily experience and exposure to the environment.

Non-formal Learning – Organized systematic, educational activity carried on outside the framework of the formal system, such as adult literacy or occupational training.

Introduction

Adult education includes the trilogy of formal, non-formal, and informal learning arrangements. The first, usually terminating in a degree or credential, is typically provided by an education and training system sponsored by the state or private institutions with parallel interests and goals directly related to societal needs. The second, non-formal, is usually defined as organized, systematic, educational activity carried on outside the framework of the formal system; examples include agricultural extension, adult literacy, and occupational training. The third, informal education, is an all-inclusive term referring to the lifelong process by which individuals accumulate knowledge, skills, attitudes, and insights from daily experience and exposure to the environment. The modifier adult emphasizes personal agency and signifies educational activities voluntarily chosen by people who have attained a stage of maturity and self-responsibility that makes them important decision makers in what and how they choose to learn.

Older adult education, a field within adult education that emerged during the middle of the twentieth century, is generally of the non-formal type. Conditions that have encouraged older adult education to flower include the lengthening of the life course, improved health and economic status among retirement-aged adults, higher rates of prior education among those reaching later life, the rising popularity of the notion of lifelong learning (whether formal or non-formal) as both a personal and public good, developmental and neurological theories advancing the appropriateness and the benefits of continued learning, and greater opportunities for learning and teaching in mid- and later life through such diverse organizations as colleges and universities, churches, synagogues and mosques, senior centers, public libraries, day health centers, hospitals, unions, and residential housing groups. Purposes of education for midlife and older adults cover a spectrum from life enrichment (often liberal arts focused) to skills enhancement and job retraining.

In a global perspective, education for midlife and older adults varies from country to country depending on economic and social conditions, traditional roles played by educational institutions, and prospects for innovation. In the UK, lifelong learning is also known as recurrent education, and on the Continent and within the United Nations Educational, Scientific and Cultural Organization (UNESCO), the term permanent education is frequently used. The phrase older adults' learning is sometimes favored by UK researchers who want to include independent learners and those who learn through voluntary service activities. Educational gerontology is both the study of how, where, and why mature adults learn and the study of how gerontologists themselves are educated.

Historical Perspectives

Adult Education Precedents

The roots of adult education programs as we know them today have precedents in both formal and informal arrangement that can be traced back several centuries. For example, American inventor and Constitutional founding father Benjamin Franklin established a weekly study group of 12 people who met to discuss community and social issues. With its origins in 1727, Junto (Latin for meeting) combined intellectual and social aims (members held annual dinner parties) and required its members to pose questions and periodically prepare and read an essay of their own making. Junto continued for 30 years and inspired numerous spin-off groups, including the first subscription library in the United States and the American Philosophical Society. Today, we would call Franklin's Junto a study circle. Though not directly derived from Junto, many lifelong learning programs in the United States, Canada, and Europe have chosen this method that combines the self-responsibility of

learners helping to educate one another in a socially conducive atmosphere as key elements of the educational experience.

Almost 100 years later, in 1826, a lecture series, the Lyceum (in ancient tradition, an association providing public lectures, concerts, and entertainment), was established to introduce adult citizens residing in small American towns and rural areas to scholarly knowledge. These lectures were an attempt to raise the educational levels of citizens who had not completed an elementary-level education. Approximately 50 years later, the Methodist Episcopal Church established a residential learning retreat or village on the shores of Lake Chautauqua in New York State to provide training for Sunday school teachers, enlightenment for church members, and the basis for a national series of tent performances that took place over several decades. Fairly nondenominational in character, the Chautauqua movement helped to introduce religious studies, liberal arts education, and the performing arts to residents in small towns across the country.

In England, adult education has even earlier roots in religious education but became secular and more widespread as industrialization fed the demand for popular democracy. Landmarks include the development of the Mechanics' Institutes in the early nineteenth century and the Workers' Educational Association and local adult education in the early twentieth century.

The idea that universities should play a major role in diffusing knowledge throughout society led in 1880s to the concept of university extension, an idea borrowed from England. At first offered through public libraries and at Chautauqua, the idea took root more successfully on college campuses to which the educated public was invited. Eventually, university extension would include correspondence teaching, lecture services, summer and evening school classes, and conferences, institutes, short-course activities, and even broadcasting services.

Adult education programs flourished in many other countries in the early decades of the nineteenth century, with the residential people's colleges (Danish *folkhjskoler*) and evening schools (*aftenskole*) gaining popularity throughout Scandinavia, particularly in promotion of civic literacy for participation in the new democracies and knowledge of discoveries arising in science and technology, and to foster a stronger sense of national identity through study and appreciation of the myths and sagas of the northern lands.

Though not residential, community colleges in the United States began almost 100 years ago when they were known as junior colleges. The establishment of hundreds of new community colleges throughout the United States in the 1960s further opened access to continued learning for adults of all ages; they covered topics ranging from mechanical and industrial skills to the acquisition of foreign languages and computer literacy.

The British Open University, an early form of distance learning using televised courses, went public in 1970, providing access to students of all ages who might formerly have been deemed unqualified. Over 200 000 people had graduated from the OU by 1998. Many other UK countries have also established OU type programs. Now the Internet has largely supplanted television as the medium of instruction and communication.

Since the middle of the twentieth century, workplace- and corporate-sponsored education has grown at an enormous rate, with participation rates surpassing even those of colleges and universities. With the advent of the Internet, distance education has spawned limitless access to adult education of all types, ranging from degree programs to online courses for personal enrichment. The Internet has supplemented the public library in giving the independent learner a powerful tool for self-directed, individual learning.

Mid-twentieth Century Emergence of Education for Midlife and Older Adults

The idea that midlife and older adults might benefit from and enjoy opportunities to initiate or renew their learning experiences built on these early innovations, though in many cases existing models were independently rediscovered. Critical additional factors can be traced to three sources: emerging theories in developmental psychology that traced personal growth well into later life, theoretical and ideological shifts in the field of gerontology, and related attitudinal shifts in the growing field of adult education.

Foremost among developmental psychologists who had a profound impact on theories of aging and later life was Eric Erikson, whose 1950 publication, *Childhood and Society*, contained what became the famous eight epigenetic stages of the life course, each stage holding the promise of a resolution to an inherent crisis of development formed by opposing tendencies. Erikson's midlife and older adult stages, generativity (nurturing that which outlives the self) and integrity or wisdom (seeing the larger patterns of life and accepting one's finitude), supported the value of continued learning. Combining this heightened appreciation for ongoing adult development with geriatrician Robert Butler's hypothesis of a universal life review process characterized by the tendency to reminisce in

later life, we see the implied rationale for learning opportunities that would promote what Abraham Maslow called (following Aristotle) self-actualization. In fact, reminiscence groups became highly popular educational activities among seniors in the 1960s and 1970s, and these in turn led to autobiographical writing and living history drama groups and other personal narrative-based forms of creative expression and performance. If midlife adults were to stay generative and older adults to find wisdom, opportunities for continued education could enhance these goals.

In the field of gerontology, the early 1960s saw the beginning of the pendulum swing from regarding aging mainly as a matter of irreversible decline in physical and cognitive functioning (the so-called failure model of aging) to a more optimistic emphasis on the strengths gained through aging. The Kansas City Study of Adult Life, one of the first large-scale demographic surveys of the aging population, culminated in the disengagement theory of aging, articulated in the 1961 publication *Growing Old*. The authors, Elaine Cumming and William E. Henry, found that as people withdrew from the workforce in retirement, they began a process of pulling back from social encounters and activities as society itself showed diminishing expectations and demands on older people. The study and theory were met with a sharp critique from scholars and researchers who argued that disengagement was not a natural process but was socially constructed and based on ignorance, stereotypes, negative self-esteem, and policies that pushed older people to the periphery of society. They countered with the activity theory of aging, which promoted the view that if older people were adequately stimulated and encouraged to stay physically and mentally active, they would show renewed vitality and contributive value. Education would certainly qualify, they argued, as one way for mature adults to remain active and productive citizens.

The field of adult education also began to stir as early as 1949 when a Committee on Education for Aging was established under the Department of Adult Education of the National Education Association (NEA). In 1951, this committee became part of the Adult Education Association of the United States. For the first time in U.S. history, this committee developed a descriptive book on educational programming for older adult learners, *Education for Later Maturity: A Handbook*.

The 1960s and early 1970s saw adult education further influenced by developments in gerontology and public policy on aging driven by various senior advocacy organizations. For example, as an outgrowth of the 1971 White House Conference on Aging, the Administration on Aging awarded a 2-year grant to the American Association of Community and Junior Colleges to explore ways for community colleges to highlight the needs of older persons and contribute to their quality of life. In addition, several community college systems tapped new funds made available through Title I of the Higher Education Act of 1965 and Title III of the Older Americans Act of 1965 to hire coordinators or part-time program directors to design and implement courses for seniors.

Still, the burgeoning lifelong learning movement should not be viewed as linear in development. The prevailing thinking in this period tended to regard the role of seniors' education as providing knowledge and skills to cope successfully with the problematic aspects of growing older. According to David A. Peterson, (1983: 219) "educational programs emphasized the crisis of adjustment to retirement and the need for outside assistance to overcome the trauma of role change." This approach corresponds to what Harry R. Moody characterized as the social service model of older adult education. As such, aging was still regarded as a problem that education could help to ameliorate. The pendulum might have been swinging, but it quivered in its arcing.

During the 1950s and 1960s, only a few educational administrators considered offering educational programs for older adults. The few programs in operation were experimental in nature, with no research base. In the early 1960s, gerontological researchers devoted considerable energy to examining links between aging, intelligence, and memory. The combined emphasis on the youth culture and research on age-related cognitive declines continued to have a negative impact upon attitudes toward older adult educational programs.

Though the 1971 White House Conference on Aging highlighted the value of education for older adults, it produced few direct results. Independent of federal legislation, a multitude of new educational programs for seniors arose in senior centers, community colleges, universities, community schools, and churches and synagogues. These programs expanded greatly in the mid-1970s and 1980s. During this period, funding from the National Endowment for the Arts (NEA) and National Endowment for the Humanities (NEH) helped support numerous educational programs, access to programs and performances, and creative works by and about older adults.

Older Adult Education and the Concept of the Third Age

For British sociologist Peter Laslett, who focused his research on the postindustrial societies of Britain and the United States, the retirement age generation of

the late 1950s to early 1960s was the first to possess the discretionary time, good health, and sufficiency of funds to determine how its members would occupy themselves in a continuing active stage, or Third Age (with dependency typically demarcating the Fourth Age). By the 1960s, unprecedented numbers of retirement-aged individuals were able to participate in leisure activities such as domestic and international travel, cultivation of hobbies, and outdoor recreation. They also had more time to volunteer, and did so in record numbers. Rising rates of high school and college completion were also attributes of this emerging age cohort. And since prior education has been the chief determinant of demand for continued learning in the later years, a growing segment of people in the Third Age represented a significant growth area for lifelong learning.

In fact, Laslett borrowed the phrase Third Age from the French L'Université du Troisième Age (University of the Third Age, or U3A), a name first proposed by Pierre Vellas, who, in 1973, founded the first U3A at the University of Toulouse. Vellas recognized that the combined vitality and longevity of many older persons in France made ideal circumstances for French universities to promote a combination of instruction for seniors, research emphasizing the well elderly, and opportunities for personal development. U3A programs subsequently spread across Europe, Britain, Australia, Canada, and, to a lesser extent, the United States. The French model featured university affiliation and instruction performed largely by university faculty. This accorded with 1968 legislation in France that required universities to provide more community education.

When the U3A idea crossed the channel this more formal, hierarchical approach was rejected and instead a self-help orientation was chosen. Consequently, British U3As are generally not affiliated with institutions of higher education and take a more egalitarian approach to teaching through use of peer study group leaders and member governance. Laslett gave the motto to the ethos of U3As in the UK: "Those who teach shall also learn and those who learn shall also teach." This French-British divergence is one among numerous examples of how political circumstances and cultural ideology have influenced the development of older learner programs.

Laslett thought that the newfound period of relative leisure must be met with opportunities for people of all classes to deepen their sense of culture and to participate in educational programs that would enable them to appreciate art, history, philosophy, music, and other subjects that were valuable to experience simply for the sake of learning itself. Without educational engagement, the Third Age would, said Laslett (1991: 170), "turn out to be indolence indefinite."

One question challenging advocates of learning in later life was the extent to which people could learn new ideas and skills and attain further stages in moral and intellectual development.

Older Person's Capacity to Learn

Research on Cognitive and Intellectual Functioning

Parallel to the emergence of older adult education meriting the attention of adult educators and gerontologists were changes in appraisal of cognitive functioning among older people. Although focus on the decline of older persons' intellectual powers characterized early research, studies conducted since the late 1960s pointed to stability in cognitive functioning over time. While recognizing decrements in some areas, researchers also emphasized older learners' relatively undiminished capacities and highlighted significant shifts in the type of intellectual abilities that may come with aging.

For example, K. Warner Schaie questioned the assumption that older people tend to function less well intellectually than younger people. He contended that all older adults do not exhibit decline. Sociologists Matilda White Riley and John Riley undertook a series of studies on intellectual functioning that showed improvement with age under certain conditions. They found continuity in intellectual functioning when life situations continued to be stimulating and challenging and when people had opportunities to use their skills and had access to educational opportunities.

Psychologist Gisela Labouvie-Vief pointed out that the early phase of geropsychology was heavily influenced by the prevailing decrement model of aging. Research presumed that physical and mental processes manifested "primary, universal, and irreversible biological concomitants of aging." But as a developmental model began to influence the direction of research, geropsychologists began to more carefully differentiate gains and losses in cognitive functioning. Hence, psychologists applied the distinction between two forms of intelligence: crystallized (derived from experience) and fluid (more biologically determined). Although the latter may show marked signs of decline with aging, the former shows less decline and longer stability. Later, the distinction between competence and performance was used to indicate differences in intellectual functioning.

Labouvie-Vief developed a trade-off view of cognitive development as a process in which some forms of intellectual integration are dissolved while

new forms of integration occur, particularly around adaptation to pragmatic necessities.

In recent years an abundance of research has focused on the role that continued intellectual stimulation and social connections make possible. Several important studies such as those conducted by Gene Cohen have shown that education and participation in the arts may actually help to delay the onset of dementia, counteract depression and social isolation, and promote the growth of new brain cells and connectivity (dendrite growth). The popular use it or lose it hypothesis has, in some cases, turned participation in continued learning into something of a cultural imperative and, at times, a scare tactic to get seniors to sign up for educational programs. There is a danger here, pointed out by Thomas Cole in his pathfinding *The Journey of Life: A Cultural History of Aging in America*, of replacing one stereotype (the frail, disengaged elder) with another (the robust, successful elder). Suggesting such direct causality between continued learning and prevention of dementia might lead to blaming the victim, as if dementia were the result of sheer indolence.

Uniqueness of Older Learners

As mentioned earlier, the tendency to reminisce as we grow older was regarded by many gerontologists as a pathology until Robert Butler showed it could be a highly positive way of integrating experiences and coming to terms with the past. As such, life review became a method for group therapy, creative writing groups, and as a source for living history drama. Some researchers went even further. They described elements of wisdom and creativity in the life review process. Not only were older adults still capable of learning and expressing themselves, but because of their treasure house of past experience, they could also be ideal students and could make excellent teachers.

If later life is regarded as a unique developmental stage with its own special tasks and opportunities, then education in the later years may be regarded as distinct from adult education. For example, Moody has argued that, unique to old age, some older learners are capable of understanding philosophical and spiritual matters that only a lifetime of experience could make possible. Just when does a person reach that threshold of unique insight? It is not a matter of chronology (how old you are) but of maturity, argued Moody.

Other researchers such as Virginia Clayton and James Birren have focused on the search for wisdom in later life as a unique characteristic of older persons. Old age, being the last stage of the life course, may be viewed as an attempt to explore the meaning of one's experiences and to integrate an understanding of these experiences or, as Schopenhauer put it, "see life as a whole." Many gerontologists and adult educators believe that self-actualization, the full realization of one's potential, should be the ultimate goal of every older adult educational program. The wisdom quest in later life would eventually be regarded as a spiritual quest and suggests another Third Age-triggered learning disposition.

Spirituality, Aging, and Lifelong Learning

Swedish sociologist Lars Tornstam proposed a theory of gerotranscendence, the notion that with age comes a radically different life outlook reflecting a cosmological shift in perception. Tornstam argued that when activity theory eclipsed disengagement theory something of vital importance was lost. Disengagement theorists highlighted an inward reflective tendency emerging in later life that denoted a change in how older people saw the world and their places within it. The problem, said Tornstam, was that these older individuals had limited resources for cultivating the new perspective that was emerging in their lives. Activity theory, he argued, for all the good it did, tended to devalue the spiritual growth of the older person, equating religiosity with social withdrawal.

From his large-scale quantitative and qualitative research – a Scandinavian version of the Kansas City study – Tornstam also found a pronounced age-related change. His subjects accepted a more nuanced sense of right and wrong, had greater tolerance for ambiguity and paradox in moral reasoning, and were able to detach themselves from the narrower cultural views of their earlier decades. In short, these individuals experienced "a new feeling of cosmic communion with the spirit of the universe," an age-triggered self-transformation that Tornstam called gerotranscendence. The Swedish sociologist argued that this was a naturally occurring transition that would be more strikingly evident if our societies (including their religious institutions) gave older people sufficient encouragement and support to make this spiritual passage to a unique late life outlook.

It is around the same time that Tornstam's articles started appearing in American journals that the spirituality and aging movement began to grow in the United States. The New York State-based Omega Institute started organizing Conscious Aging conferences in 1992 with a host of high-profile figures such as counterculture guru and spiritual author Baba Ram Dass (who had recently discovered his own aging and written a book about it), Jewish mystic

Rabbi Zalman Schechter-Shalomi, social activist and Gray Panthers founder Maggie Kuhn, and other visionaries who championed the role of both the secularly wise, politically active senior and the spiritual elder. Though Tornstam was not part of this cast of conscious aging advocates, his research-based theory and Erikson's model of development supported the views espoused at these conclaves.

In the field of aging, concurrent with this movement, the American Society on Aging (ASA) launched a new constituent unit, the Forum on Religion, Spirituality and Aging (FORSA), which grew quickly in membership. From Rabbi Schachter-Shalomi's book, *From Age-ing to Sage-ing*, a number of Spiritual Eldering Institutes were established to do what Tornstam suggested was missing, namely, to nurture older people's capacity for reaching a new level of development so that they might play new roles in society as spiritual mentors to younger generations.

Scholars, advocates, and religious leaders did not cause people to suddenly want to become spiritual elders. This trend reflected a worldwide revival of religious interest, if not zeal, that also swept into the older population and into the field of aging. The trend has also had a profound impact on expanding mainstream older learner programs to include training in yoga, meditation, and Tai Chi and numerous courses on comparative religion, mysticism, Chinese medicine, ancient and modern mythology, and so on.

Compensation and Learning Styles

Paul Baltes and his colleagues at the Max Planck Institute for Neurological Research in Berlin further supported the value of education. They examined compensatory strategies people employ as they grow older. The Berlin group distinguished between two types of mental activity: (1) the biologically shaped hardware of the mind, which operates the speed and accuracy of memory, sensory input, ability to make distinctions and comparisons, and ability to put things into categories (also termed cognitive mechanics), and (2) the software of the mind, more a product of culture, upbringing, and environment, including reading and writing skills, self-knowledge, and coping skills (which Baltes calls cognitive pragmatics).

Baltes and his associates found that although older persons' memory capacity would increase if they participated in memory training techniques, they would still not reach the level of younger persons who received the same training. They concluded that the hardware of the mind does show a decline with age. But when it came to real-life problem-solving tests – for example, counseling a threatened suicide or advising a 15-year-old girl who wants to get married – they found no major differences among those 30–70 years of age. In fact, those above age 60 were as likely to rank among the top 20% of skilled 'wisdom performers' as younger adults.

The Berlin researchers coined the infamous phrase selective optimization with compensation, to describe how older people offset slowing down in some areas of cognitive and physical skill. He cites the example of Arthur Rubinstein, the famous pianist, who concertized well into his later years. Asked how he managed to sustain his career so successfully, Rubinstein commented that he limited his repertoire to fewer pieces (selection), practiced longer (optimization), and played slow movement slower so that faster movements sounded comparatively faster (compensation). Similar examples abound in literature and film about aging competitive athletes who learn to use brain as well as brawn. They draw on hard-earned experience to strategize and outfox their opponents, reserving their strength for exactly the right moment, rather than relying on endurance and speed. Similarly, many people develop tools and learning strategies such as mnemonics (memory techniques) to aid in their acquisition and retention of information.

Motives of Older Learners

Instrumental-Expressive Continuum

Considerable research has centered on the dichotomous pair of terms expressive and instrumental to characterize learner motives. Learning for its own sake has been classified as expressive, whereas learning directed toward some further outcome or external objective is said to be instrumental. Similarly, the term enrichment is often used to describe learning undertaken to enhance personal growth, while skill-building or skill acquisition-motivated learning suggests some practical application. Educational leaders and administrators often must determine the mix or balance of these two types of learning goals in order to satisfy their existing or potential clientele. However, the distinction is not hard and fast, since the same learner may hold both motives simultaneously, for example, signing up for a computer literacy course in order to keep up with the times (enrichment), to start a correspondence with distant grandchildren, and to make birthday cards (the latter two qualifying as skill building).

Problem of Determining Motives

The majority of surveys of older learners concur that the top-ranked motive of those enrolled in liberal

arts-focused educational programs is intellectual stimulation, a seemingly expressive or enrichment orientation. But this term may cover a wide variety of motives, ranging from the desire to increase one's appreciation of literature, philosophy, or history to the mental challenge of learning a foreign language. Intellectual stimulation may mean attending an international affairs lecture series to ensure that one is a better-informed voter. Though all these motives, both expressive and instrumental, qualify as intellectual stimulation, the term covers more than it reveals.

The scholarly literature on the motives of older learner is fraught with contradictory findings. This may be a function of the context in which the studies were conducted. For example, studies conducted at senior centers in the early 1970s were likely to yield instrumental orientations because the types of programs offered tended to deal with coping issues and hobbies. By contrast, studies of participation in the travel-learning program Elderhostel tended to produce the opposite results, as most people chose those courses for intellectual and personal enhancement. Researchers Paul Wirtz and Ivan Charner pointed out that the hypothesized instrumental-expressive continuum used in various studies may force participants to choose among artificial categories. Hence, inconsistent findings may be the result of utilizing scales that lack psychometric validity. Something as subjective as intellectual stimulation may not lend itself to quantitative research tools, the method used in most of the studies.

The National Retired Teachers Association (NRTA), then a division of AARP, took another approach to older learners' motives in 2000. The AARP Survey on Lifelong Learning was conducted via telephone and online with 1019 individuals, focusing on "how and why people over 50 learn about new things." Consequently, the findings emphasized learning behaviors such as acquiring information from newspapers, magazines, books and journals, and online resources (half the respondents responded online). Overwhelmingly (93%), respondents said they wanted to learn "to keep up with what's going on in the world," for "spiritual or personal growth" (92%), and "for the simple joy of learning something new" (91%). The study included a highly diverse population, so it was not surprising that only a small percentage (15%) strongly preferred a formal teacher–classroom situation while a majority (60%) strongly preferred an informal, hands-on approach.

Life Tasks, Needs, and Wants

Louis Lowy and Darlene O'Connor found a useful way to resolve the contradictions and ambiguities of the older learner motivations when they constructed a matrix combining instrumental and expressive orientations with need categories (e.g., coping, contributive, influencing) developed by Howard McClusky. They produced a holistic overview that would integrate a wide range and mix of learner goals and orientations.

Reviews of seniors' educational motives show that, like adult learners in general, seniors exhibit a wide diversity of needs, interests, and wants that may be conditioned by socioeconomic and educational backgrounds, the institutional setting where programs are offered, and the existence or availability of opportunities.

Empowerment and Socialization

Another motive or consequence of participation in forms of continuing education is empowerment. Older learners may find peer support, heightened self-esteem, a renewed sense of efficacy, and political solidarity through involvement with peers in educational settings. Numerous studies of creative and life history writing groups, especially those primarily involving women, reveal that finding one's voice and being able to tell one's story may have enormously liberating consequence. Validating one's life experience can be an important part of continued learning.

Many informal types of lifelong learning depend on participants playing volunteer roles as teachers, committee members, and part-time administrators. The entire enterprise may constitute a learning community so that members gain a new venue for socializing and making new friends through the valued affinity of education.

Adding to and supporting the role of education for building volunteerism among seniors, the work of gerontologists such as Sandra Cusack and Wendy Thompson in Canada has demonstrated the value of leadership development programs for older adults.

Emancipation and empowerment are major frameworks for British experts writing about older learner programs. Many of them lament the absence of the national government's role in providing resources for lifelong learning for older adults, regarding it as another example of the marginalization of mature individuals.

Older Adult Education Programs and Public Policies Since 1960

By the time of the early 1960s, the impact of longer life expectancy and steady decline in the average age of retirement in the United States and other postindustrial societies yielded noticeable growth in the

population of retired citizens. Many adult education leaders as well as gerontologist asserted that seniors needed the knowledge and skills to cope successfully with the problematic aspects of growing older. Another common and related rationale of the period was that continued mental stimulation in the context of social learning would help prevent premature institutionalization. While in many countries the rise of older learner programs was independent of government and public policy, new forms of lifelong learning reflect predominant cultural attitudes and changes in health care and social support mechanisms such as public and private pensions. A few examples help to illustrate this point.

Normalization and Tuition-free Programs

When, in the 1970s, the normalization movement in the United States brought the mass exodus of thousands of patients from mental hospitals across America, discharging them to the newly established community-based care network of mental health centers, a parallel mainstreaming attempt occurred in the realm of older adult education. Some 39 state legislatures enacted bills to allow people over age 65 (or 62, depending on the state) to enroll, tuition-free, in public colleges and universities as space permitted. Rather than segregating older people, argued advocates, society should be finding ways to integrate them with other generations. In most cases, this legislation was gratuitous since no funding was attached. Consequently, most colleges and universities did little to publicize the mandated opportunity and few of the empty seats were taken. There were, however, a few notable exceptions. Because of undergraduate enrollment shortfalls of the period, several universities such as Syracuse and Western Washington State University actually established dorm space for senior housing on the campus and (e.g., at WWSU's Fairhaven College) promoted intergenerational learning opportunities. However, these experiments were short lived. In contrast, many community college systems did find state funds available to partner up with senior centers to deliver classes on site. This innovative model lasted perhaps a decade until economic pressures and the demands of other needy groups (e.g., immigrants, Vietnam veterans, women returning to school) gradually squeezed out these programs.

Changing Attitudes Reflected in the New Nomenclature

Cross-fertilization between scholars and researchers who advocated the value of education as a catalyst promoting development in later life (the humanistic gerontology school), and innovative leaders in adult education such as Malcolm Knowles, whose adopted use of the term andragogy highlighted the uniqueness of adult learner-centered education, generated the radically new view that older learner programs could serve as engines of lifelong development and even social change. Extending traditional psychological developmental life stage theories into new, uncharted territory, these programs would reflect the claim that growth did not end with the consummation of adolescence.

The names of the new older learner programs of this period reflected the shift in assumptions by playing on the irony of substitution. So from Youth Hostel came Elderhostel, the low-cost, travel-learning program for people over age 55 that was launched in 1975. These 1-week-long summer stays in Spartan college dorms, and journeys through the halls of ivy, would eventually lead to a huge, year-round, international program in which elder hostellers would have experiences usually reserved for youth. Similar substitutions of age for youth produced senior colleges, Gray Panthers, adult day care centers, senior centers, drama groups such as the Autumn Players, and later the federal program Senior Corps. The fresh nomenclature challenged the myth of disengaged seniors and replaced it with an image of the active, if not youthful, and certainly resourceful, older person. After several decades, the names no longer conveyed the same element of surprise, which is why organizations started to discard or modify them in the 1990s (e.g., senior centers became enrichment centers).

After years of pent-up demand, the surge of older learner programs in the 1970s and 1980s was remarkable, the product of a revolutionary change in attitudes about aging and later life, of more effective senior advocacy, and, demographically, of a growing number of retirees with the time, energy, and motivation to pursue continued learning. It was as if the older person had been suddenly discovered as a capable and resourceful individual whose vast developmental potential was still intact. The fact that activity theory totally eclipsed disengagement theory is borne out by changes in social policy. Mandatory retirement was gradually eliminated via the Age Discrimination in Employment Act (ADEA), which took effect in 1979 (amendments occurred in following years). By the time of the United States Bicentennial, perception of senior citizens (to use the commonest term of the period) was shifting from that of the poor, dependent, marginalized elder to individuals perceived both as deserving and (e.g., in the popular *Foxfire* books) as rich repositories of cultural wisdom if not great moral tales of courage

and survival – especially through the period of the Great Depression.

Lifelong Learning Institutes and Universities of the Third Age

It is in this same period that college- and university-based Institutes for Learning in Retirement (ILRs, later renamed Lifelong Learning Institutes, or LLIs) arose. The prototype for subsequent LLIs was the Institute for Retired Professionals established in 1962 at the New School for Social Research (now New School University) in New York City. Only a handful of the member-led, member-taught, educational programs had appeared by the mid-1970s but by the mid-1980s there was a sharp rise in the rate of new programs started each year, until, by 2000, there were more than 400 of these programs across the United States and Canada.

LLIs were unique not only because the members were in charge but also because they were based on a financial model that required participants to help pay for the cost of their own continuing education. Today, this financing method may seem unexceptional, but at the time the idea that older learners should pay for their own education was unprecedented. Previously, older learner programs generally depended on the largesse of private and public foundations and government subsidies. That funding basis explains why these programs were so often episodic, coming and going in repetitive cycles of demonstration projects that left no infrastructure behind. Perhaps the self-financing business model of most continuing education departments influenced LLIs where, institutionally, they were most often located. This radically new idea of self-financing programs was a harbinger of the future.

Today, the network of LLIs is loosely linked through affiliation with the Elderhostel Institute Network (EIN), a consortium supported, in part, through the largesse of Elderhostel and that has an extensive website that lists member programs, posts monthly newsletters, and provides extensive material on curricula, bylaws, how to start an LLI, and so on.

A new catalyst helping to promote establishment of new LLIs and expansion of existing ones is the Bernard Osher Foundation, which, since the early 1990s, has generously funded 79 Osher Lifelong Learning Institutes (OLLIs) and aims to bring that total to 100 over the next few years.

The counterpart to LLIs in the United States and Canada are the Universities of the Third Age, which, as mentioned earlier, began in 1973 in France and subsequently spread throughout Europe, the UK, Australia, New Zealand, South America, and Eastern Europe. The growth of U3As is reflected in the 574 groups, with a total membership of 153 443 as of February 2006, in the UK alone. Some U3As use a study circle approach with all participants helping to educate one another, while others use expert-led formats. Many national U3As participate in the International Association of U3As, or AIUTA (the French acronym).

Age-Segregated Programs and Empowerment

A debate in the United States in the 1970s concerned whether age segregation or age integration was the right direction for older adult education to follow. The normalization, mainstreaming argument pointed toward a future society based less on distinction of age than on needs and interests, one in which there should be more blending of generations in educational settings. But the majority of seniors seemed to prefer learning experiences shared by and with their age peers. And certainly the various organizations that depended on state, federal, and private foundation funding sought to retain their positions as the hosting sites of such programs.

Another inner tension concerned whether emphasis in older learner programs should be placed on humanistic gerontology's Maslovian self-actualization ideal or on the emerging political advocacy emphasis of empowerment. A telling example is the National Council on Aging (NCOA) anthology series that was at first called "Self Discovery through the Humanities" and later modified in the mid-1980s to just "Discovery through the Humanities." What did this small excision signify? The discussion group participants were not only to see themselves in the mirror of literature, history, and philosophy but also to peer through a "window into the lives of others." They were not only to grapple with meaning and wisdom in their later years (the Eriksonian emphasis) but also to find their place "in the fabric of American history," and to gain a voice to assert the dignity and resourcefulness of the now more visible, socially and politically active senior adult.

Participation Rates and Implications for the Future

Participation Rates

Since the 1970s, educational participation rates for people 55 and over have climbed steadily. More recently, according to the National Household Education Surveys (NHES), during the 1990s, the percentage of people in the United States aged 66–74

who took at least one adult education class in the previous year more than doubled – from 8.4% in 1991 to 19.9% in 1999. The biggest growth in participation of individuals aged 55–74 was in community-provided, non-formal education. This includes not-for-credit courses, workshops, and seminars offered by churches, libraries, department stores, senior centers, and so on, for which the rate went from 4.6% in 1991 to 11.6% in 1999. About 5.5% took courses in a school or university in 1991, rising to 8.6% in 1999. The increase among the 'young-old' surpassed that of any other age group.

Age-related role expectations still seem to be a defining factor for workplace educational participation. Participation rates for job-related education reveal modest increases compared to younger age groups. For example, between 1991 and 1999, the rate of those ages 48–56 participating in educational programs offered by business or industry increased from 12.6 to 19.6%, while for the age group 66–74, the rate rose from 2.0 to 4.8%. This reflects a continuing trend, as business and industry prefer to invest their training dollars in the younger workforce.

Degree of prior education remains the chief predictor of educational participation for adults of all ages. But greater visibility of educational opportunities and a growing acceptance of the value of lifelong learning were also factors. In all likelihood this trend will continue as an even better educated American Baby Boom population enters the retirement period and because the average age of retirement in the US is holding fairly steady at about 63. However, another strong trend, desire to return to the workforce after formal retirement in both full- and part-time second careers, may alter this pattern. If the high percentage of today's Baby Boomers actually does seek postretirement careers, there should be a huge increased demand for instrumentally oriented continuing education classes.

Unprecedented participation rates of older adults in adult education confirm an overall pattern – the emergence of a so-called lifelong learning society. It is estimated that almost half of the entire adult population in the United States participates in organized education in a given year. With regard to older adults, the United States is in what might be called a rehearsal stage. While the United States is certainly an aging society, with a median age of 36 that will rise the 39 by the year 2010, it is the aging of the huge Baby Boomer population (those born between 1946 and 1964) that will truly challenge cultural and educational institutions. Currently, those 65 and over make up 13% of the US population and those 60 and over comprise about 16%. The United States actually saw little growth in the percentage of its 65 and older population during the 1990s because of the low birth rate for the cohort born during the era of the Great Depression of the 1930s and into the early part of the 1940s. But by the year 2020, those 65 and over will comprise 18% of the US population, and that percentage will continue to rise until the 2050s (23%). The percentage of college-educated older adults will rise from the current 12% to 20% by 2010 and will continue to rise dramatically thereafter. Moreover, this rising percentage applies to a numerically vastly larger cohort.

In the current rehearsal stage, we have seen demand for education growing as education in the later years is viewed as valuable for preparation for second or third careers, personal enrichment and psychological growth, prevention or delay in the onset of cognitive decline, and aiding in adjustment to life beyond or after work. In all likelihood, the demand for educational opportunities will overwhelm current providers in terms of both numbers and range of curricular diversity. People in every industry in the United States have been gazing into crystal balls (or hiring consultants) to predict what Baby Boomers will want in their role as consumers. And this is no less true for providers of lifelong learning opportunities. But thinking only in terms of consumers may be a big mistake. What is called for is new leadership and vision.

Organizational Leadership

Currently, organizational leadership in older adult education in the United States is fragmented and decentralized. There is no organized group lobbying Congress or state governments for increased funding to educational programs primarily serving older adults. There are, however, a number of national associations with subcommittees or affinity groups focused on older learners. For example, the American Society on Aging has its Lifetime Education and Renewal Network (LEARN), composed of about 450 individuals whose work (usually only in part) is associated with some form of older adult education. And the Association for Continuing Higher Education (ACHE) has its Division of Older Adults. The Association for Gerontology in Higher Education (AGHE) focuses primarily on professional-level teaching of gerontology and only to a slight extent on education for seniors. As mentioned earlier, a majority of the LLIs are members of the EIN, affiliated with the Elderhostel organization. EIN's main activities consist of biennial regional conferences, maintenance of an informative website, and advice on how to start new LLIs. In the UK, the National Institute of Adult Continuing Education – England, Wales (NIACE) has

an Older and Bolder Initiative section that provides an information exchange mainly for professionals involved in older adult education but also for older learners through email groups.

As mentioned, the European and UK counterparts to LLI, the U3As, have national associations in many host countries, and many of these national units send representatives to the International Association of Universities of the Third Age (AIUTA) annual conference.

Professionally speaking, older adult education has no real independent standing. As a field, it is a subject of peripheral concern to both gerontological and adult educational organizations. The field lacks monetary significance since it is not a major revenue source for institutions of higher education, and only a few nonprofit organizations, for example, Elderhostel, perhaps the most significant, derive significant income from offering services and programs to seniors. Education for seniors is seen as an important marketing tool for investment companies, banks, hospitals, and cultural organizations that regard it as a mechanism to lure in potential clients, contributors, and members. In the sphere of higher education in the United States, affiliated LLI programs have proven to be a point of access to successfully solicit major donors.

Even in the area of research, where millions of dollars are spent on the causes of and potential remedies for cognitive decline as related to aging, a scant amount of research looks at the potential impact of older adult education on sustaining cognitive functioning. And little research involves applying what has been learned in cognitive science to better ways to educate or foster older adult learning.

Prospects for the Future in Cross-cultural Perspective

In the near-term future (the next 15 years), as a correlate to these trends, lifelong learning opportunities will increasingly become a function of the marketplace. Those who are in sufficiently good health are motivated by having enjoyed prior years of education (the main predictor of participation), and can afford to enroll in LLIs, pay for travel-learning excursions, sign up for continuing education courses, register for back-to-campus alumni seminars, access Internet educational sites, and choose from among a cornucopia of other lifelong learning programs, will reap the benefits of successful aging. Educational programming for Baby Boomers (the neo-elderly) especially will be a thriving business that deans of continuing education programs and directors of for-profit travel-learning companies, among others, are (or should be) discovering. We should expect an increase in demand for vocational education for second and third careers with likely emphasis on technical, managerial, and business-related training needs. Also, retirement communities associated with colleges and universities should experience a surge in growth.

Baring a change in public policy, those who do not fare so well because of poor health, limited incomes, and lack of motivation because of more restrictive prior education (especially minority elders) will find comparatively little from which to choose in the way of intellectually challenging programs. In fact, those who do not fit the image of successful aging will be chastised as failed agers, a moral castigation of those who seem not to have seized the opportunity to age well. It does not require much reflection to see that this scenario is an extension of current trends.

While current social and role theories of aging will remain relevant for certain subgroups of future seniors, it is probably what British theorists Chris Gilleard and Paul Higgs call the cultures of aging framework that will predict an emerging trend in which one finds few vestiges of solidarity among older citizens, a shunning of age-linked labels, and attitudes leading to a self-centered consumer society in which only isolated affinity groups, such as same-church elders or people living in gated, age-qualified retirement communities, will identify with one another. The gulf between the haves and have-nots, the successful and the disenfranchised future senior, will only widen. Calls for public funding for educational programs for the underserved will mainly fall on deaf ears. The disenfranchised will have become the neo-disengaged elders.

Educational programs that hold onto the current nomenclature – self-identified as for elders, for retirees, for seniors – will either dwindle or will mainly attract a frailer, older population. This trend is already occurring at some of the most popular Elderhostel sites such as the famous music conservatory the Peabody Institute and is very much like the trend in continuing care retirement communities (CCRCs), where average entry age hovers around 80. Meanwhile, other forms of lifelong learning will continue to grow in popularity as people with higher rates of college completion reach midlife and encounter the various decision points. This is not to say that the ideological dominance of the laissez-fare economy of our consumer-oriented societies is the most desirable direction, for certainly any ideal of equal access following principles of distributive justice seems overshadowed by other criteria and social values.

Lifelong learning programs in the United States and Canada will continue to mirror the economic systems of these countries. These programs – whether

conducted through colleges, senior centers, hospitals, libraries, or religious congregations or sponsored by private sector organizations such as banks, department stores, and travel-learning agencies – will remain market driven and increasingly require full fees or some form of co-payment for enrollment. Trends in other countries may be somewhat different.

Currently, there are more than 20 000 free universities for old people in China whose purpose or rationale, their mission statements proclaim, is to enable an older citizen to carry out his or her sacred duty to society by avoiding boredom and depression, gaining knowledge of hygiene and herbal medicine, and learning ways to provide care to others. An older learner in China is responsible for trying to remain as independent as possible while helping to relieve the health-care burden shouldered by the state. Yet, as China moves toward a more free market economy, this educational policy, mainly directed toward a generation of people who sacrificed many of their life opportunities during China's tumultuous years of war and revolution, will probably change direction.

In terms of the content of curricula, many older learner programs, especially in the United States and Canada, will continue to exhibit a fair degree of independence since these programs are not tied to credentialing guidelines and are far less likely to be censured for teaching controversial subjects than public secondary and postsecondary schools. A look at any of the curriculum catalogs of LLIs in the United States reveals a wide spectrum of courses ranging from "The Human Genome Project: Hope or Hype?" to "Define Your God." LLI members teach these courses after selection by a curriculum committee of peers.

Again, to draw cross-national comparisons, the almost counterculture tableau of LLI course offerings is not found in Spain, where some 50 older learner programs are administered by universities, taught by their professors, and require older students to enroll in a 3-year curriculum with limited options for elective courses. The academic authority-based *in loco parentis* approach is a by-product of Spanish history and culture. Most of the older students did not formerly have the chance to attend college during the years of the Franco regime, and Spanish universities have not, until recently, played the role of American ones with their continuing education departments serving a wide variety of purposes ranging from postdegree professional education to personal enrichment. The Spanish universities are not about to invest their older students with the power to shape their own curricula, nor is this generation of older Spanish students of a mind to regard themselves as capable of playing such a role. Whether Spain will gradually move in the direction of the United States, liberalizing and commodifying continuing education for future seniors, remains to be seen.

In the United States, a strong push is under way to convince the emerging mature generation to consider the needs of others. The message that civic engagement advocates bring to the so-called Me Generation is that freedom should not be uncoupled from responsibility. Great concern is expressed, for example, in a 2004 report from the Harvard Center for Health Communications that Baby Boomers will not volunteer to the degree of their parents' generation and that even if they did, the infrastructure that would enable society to use them appropriately does not exist. While educational programs for older learners are not obligated to incorporate community service as an element of their mission and rationale, the combination may hold particular appeal for the socially conscious neo-elder. Perhaps this option should be part of a learning, leadership, wellness, and service quaternary for future programs.

See also: Adult Education; Learning.

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Emotions

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Glossary

Emotions – Brief responses involving physiological, experiential, and behavioral activity generated by either an environmental or an internal stimulus.

Introduction

Emotions are relatively brief responses involving physiological, experiential, and behavioral activity generated by either an environmental or an internal stimulus. They can be characterized as globally positive or negative in valence, or as more differentiated states (e.g., anger, fear), each with its own particular functional explanation. Emotions are part of the larger concept of affect, which refers to both short-lived emotions and longer-lasting moods and feeling states. Emotions have been characterized as human universals, with stability across different social and cultural groups. They are influenced by environmental factors as well as internal regulatory mechanisms that can significantly affect the experience, expression, and perception of emotion. Healthy adults of all ages experience, express, and regulate their emotions. Key questions to be answered in research on aging and emotion include the impact of age-related processes (e.g., memory and cognition) on the experience, expression, and perception of emotion and the role of individual differences (e.g., personality) and social structural factors as moderators of the emotional lives of older adults. Psychosocial and physiological approaches to studying emotions and aging have revealed both changes and continuity in the emotional lives of older adults. Life span developmental perspectives on emotion and aging provide an interpretive framework for current research on normative changes in emotion with aging.

How does Aging Impact Emotional Experience, Expression, and Perception?

While studies of reported emotion in young, middle-aged, and older adults have revealed interesting patterns of change over time, many important issues surrounding the experience, expression, and perception of emotion with aging remain unresolved. In what has been called the paradox of aging, it appears that a stable or even increased amount of positive affect is associated with increasing age, while negative emotion in general decreases, leading to a greater emphasis on positive emotion in older adults, despite the gradual physical and cognitive declines associated with aging.

Specific emotional strengths that have been found are a focus on positive emotions and stimuli that produce them, the tendency to downplay the experience of negative emotions, and the ability to view past and present experience with mixed emotions (poignancy). Older adults have been described as having a realistic explanatory style, an absence of dispositional pessimism, and selectivity in goal pursuit and social relations.

In self-report findings, older, compared with younger, adults reported greater overall pleasure and arousal when viewing affective images designed to evoke positive, neutral, or negative feelings. Older adults in a large community-based study reported lower levels of anger than younger adults. Experience sampling of positive and negative emotion during mutual reminiscing was compared with emotional experience during other activities in older and younger adults. Older individuals reported increased positive emotion when exchanging stories about the past with others compared with younger adults, particularly when they were remembering positive events. Finally, the impact of chronic pain, increasing with age, is not reflected in an increase in pain reports among adults after age 70.

Emotional differences between older and younger adults also extend to social contexts and personal experiences, particularly with regard to close relationships. Older adults have reported that they are less often upset by interactions with family members and that they are less likely to report responding to interpersonal tensions with actively negative strategies, such as yelling. When negative emotion categories reported in response to remembered instances of interpersonal tension were investigated (anger, sadness, and non-specific negative emotion), older adults were less likely than adolescents or young adults to report anger and intense aversive experiences in general. With aging, the amount of emotional support given and received declines, and exchanges of social support change in nature, becoming more balanced over time. Older adults, it has been argued, regulate their emotional experiences by actively focusing their attention on close relationships most likely to yield emotional rewards. Studies of older married couples have confirmed that within these relationships, they may experience increased affection and decreased negative emotions. Others have proposed that developmental processes combined with cognitive strengths throughout adulthood facilitate cognitive affective complexity and can lead to improved emotional coping in older adults. However, more work is needed on the social networks of older adults, particularly with regard to reported versus desired amounts and diversity of contact in the presence of structural and physical constraints on social activity.

In the expressive and perceptual domains, research on aging and emotion has produced a more complex picture. Emotional expression generally decreases with aging, although older adults retain the ability to produce emotional expression voluntarily at the same levels as younger adults. Although expression may be less intense, this does not mean that older adults have a more neutral appearance to others. Due to changes in aging skin and appearance that are unrelated to emotion, older adults, especially the very old, are judged negatively during neutral facial expression, because wrinkles tend to mimic patterns of negative facial expression. Neutral faces of older adults, probably for this reason, were perceived as more emotionally intense in a study of posed facial emotional expression. Additionally, the expressions of older posers were rated significantly less accurately, and with significantly less confidence, than those of younger posers. Interestingly, there were no reported differences in intensity between younger and older facial expression posers for negative or positive emotions, suggesting that the capacity for voluntary emotional facial expression in older adults is similar to that in younger adults.

While research has concentrated on reported or expressed emotion in older adults, emotion perception and responsivity is also an important facet of emotion in aging. Adaptive developmental theories of emotional change rely on the assumption that emotional abilities remain intact in healthy older adults and that changes in emotion reported by older adults represent developmental psychological change, rather than degenerative changes in emotion-processing abilities. Gauging emotion perception abilities has been one approach to explaining the role of emotion in aging and to addressing important questions regarding the source of emotion differences between young and old.

There is some evidence that emotion perception abilities such as recognizing facial expressions of emotion undergo a general decline that is distinct from other perceptual and cognitive abilities. In a study of facial perception, older participants perceived lower levels of emotional intensity in sad and happy faces in a study of the perception of faces and accompanying stories. Compared with the younger group, older adults perceived neutral faces as showing low anger levels. Older adults also rated protagonists in stories as experiencing low levels of fear and rated some aspects of emotions portrayed in facial expressions and written text as less intense, although most differences could be explained by age-related differences in anxiety, depression, and intelligence test scores. One study of the perception of facial expression showed that older adults had deficits in the perception of negative and neutral expression, but not positive expression.

When viewing emotion-inducing slides in a standard laboratory paradigm, older adults exhibited significant differences in brain activity, as well as decreased activity in the corrugator muscle of the face (associated with negative emotion) and heart rate deceleration compared with younger adults. Studies

conducted in a more naturalistic context that compared older and middle-aged married couples engaged in discussions of marital conflict showed that emotion-specific autonomic activity was similar across different age groups. Facial expressions of emotion in the older adults, however, were configured differently from those of younger adults, with the quality of emotion expression rated lower. Physiological changes were consistent with but of lower magnitude than those found in younger adults. These age differences suggest that older adults have differential reactivity to both laboratory-presented affective images and the emotional context of social relationships. They also indicate that age-related changes in emotion are not uniform across emotion response systems. Several researchers have reported that older adults show a decrease in their perception of emotions such as fear and sadness, but that perception of another negative emotion, disgust, is preserved. The relation between physiological measures of emotional response and self-reported emotion on which life span developmental theories of aging have generally been based is not clear. An increased emphasis on differentiating emotions beyond the negative–positive dichotomy may help to explain contrasting results of earlier studies.

Neurobiology of Aging and Emotion

Studies of both structural and functional changes in the brain indicate that there may be important changes, not just in the response to emotion, but also in the neural systems that respond to emotional stimuli in older adults. In general, there is less reliance on limbic areas of the brain and more reliance on the frontal and prefrontal lobes when emotion perception tasks are given. For example, when discriminating emotional facial expressions, the left frontal regions of the brain were activated in older adults and the amygdala and surrounding limbic areas were activated in younger adults. In a similar study using functional magnetic resonance imaging, older adults observing faces showed less brain activity in all regions than younger adults while viewing faces with positive, negative, or neutral expressions. These results support the general conclusion that medial temporal lobe structures associated with emotion perception (amygdala, hippocampus, and parahippocampal gyrus) are significantly affected by age. Some researchers have proposed that it may be this shift in older adults toward using the prefrontal regions to process emotional stimuli that explains the enhancement of positive memories with age. The preservation of emotions in older adults may be due in part to this shift of emotion perception emphasis from medial temporal regions of the brain to regions in the frontal lobe that remain at a high level of functioning during aging. An alternative theory of emotion, aging, and brain function proposes that the emotional deficits of older adults can be explained as a result of reduced asymmetry between the cerebral hemispheres. Results from studies of perception of emotional facial expression support, in part, the association of lowered emotional perceptual ability and reduced asymmetry in brain functioning during emotion perception tasks.

Role of Individual Differences in Emotion and Aging

Individual differences can be predictive of emotional experience, expression, and perception. The role of individual differences in the emotions of older adults is relatively unknown. While differences in personality, gender, physical and mental health, education, intelligence, and other factors may have consistent effects on emotions in both younger and older adults, it is also possible that some of the emotional characteristics of older adults can be explained in reference to these differences.

Personality is known to be a significant predictor of emotion in adults of all ages. Although changes that result from major alterations, such as the death of a spouse, can cause shifts in personality, in general the stable association of extraversion with positive affect and neuroticism with negative affect remain applicable in older adults. Individual differences in personality, combined with stressors, explain some of the differences in vulnerability to negative emotions and symptoms of mood disorder in older adults. In a study of older adults ranging in age from 70 to over 100 years old, the personality factors extraversion and neuroticism were the largest single predictors of positive and negative affect.

Gender differences in emotion in older adults also have been found; women in general appear to experience more emotion and simultaneously to regulate their emotions more strongly. Older women were more emotionally distressed and distressed for longer periods of time than men by interpersonal conflicts within their social networks. While describing aspects of their own personalities, older women were significantly less variable over time than younger women. This decrease in self-reported emotional variability has been linked to increasing emotion regulation ability with aging and with decreases in intensity of positive and negative affect. Researchers have also found a reduction in symptoms of depressed mood in women aging from late 40s–early 50s to late 50s–early 60s. Differences in menopausal

status predicted symptoms of depressed mood at an 11-year follow-up among women, suggesting a hormonal basis for emotions and aging.

Health, particularly physical health, is likely an important factor in the emotions and abilities of older adults. While the emotions of relatively healthy, community-dwelling adults may represent a preserved strength, the emotions of older adults with physical disabilities present a very different picture. Poor physical health was associated with lower levels of life satisfaction in a study of well-being in older adults. The effect of poor health on emotions may be limited to its tendency to lower positive affect, while having no effect on negative emotions. In another study of aging, emotions, and subjective well-being, however, physical decline was linked to lower positive and higher negative affect. It was not, however, associated with life satisfaction.

In contrast, individuals characterized by physical hardiness and high levels of activity were less likely to be clustered in a group of individuals characterized by high negative affect in an analysis of socioemotional patterns in older adults. Active individuals in good physical health were significantly more likely to cluster with individuals that showed a relatively calm and low negative (and low positive) affect profile. Individual differences in physical health and functioning clearly affect emotions in older adults yet have not been widely considered in analyses of normative aging.

The effects of other individual differences, such as intelligence, education, and social status, on emotional experience have not been widely researched. Intelligence has been found to predict emotion in older adults, with higher intelligence associated with higher levels of positive and negative affect. The resources of crystallized intelligence and cultural knowledge accumulated during adulthood are related to cognitive affective characteristics such as coping styles. Intact cognitive abilities clearly play a role in helping at least some older adults cope with difficulties in ways that maximize emotional well-being. Many older adults also have been shown to maintain a relatively high level of happiness. It is not known whether the results found in this particular sample contrast with those of younger adults. Most studies have generally concluded, however, that even when interactions among these variables and age have been controlled, there remains a general bias toward positive and against negative emotion in old age.

Emotion and Cognition in Older Adults

Investigating emotional and cognitive processes in older adults has the potential to resolve the question of whether emotional change is a relative strength of aging that compensates for cognitive decline or whether it is an additional area of decreasing function in older adults. Cognitive characteristics and emotional health are clearly linked, and the connection may have benefits that work in both directions. Some studies have found that an emphasis on emotions in the psychology of older adults has beneficial effects on other cognitive and emotional aspects of everyday life. For example, episodic memory has been shown to be related to positive affect in older adults but not in younger adults. In the same study, other abilities such as recognition were not affected by self-reported affect, suggesting that the effect is specific to particular aspects of cognitive performance. Memory for negative images, in contrast, showed an age-related difference in a study in which older and younger adults were tested for their recall of positive, negative, and neutral emotion-inducing images, with older adults performing more poorly for negative images only. Whether or not this difference in performance reflects a loss of the capacity to respond to negative emotional input or increasing emotion regulation is not known.

Other studies have found that emotional effects on cognitive tasks are similar in younger and older adults. Older adults showed a pattern of lexical responsivity to emotional words similar to that of younger adults in an emotion induction study. Older adults that had listened to music inducing sadness responded more quickly to sad words, and those that had listened to music inducing happiness responded more quickly to happy words. Affective priming in older adults was also found to be similar to that in younger adults, with the exception being the greater reliance on the affective prime among older adults that reported a need for structure. This can be interpreted as an indication of the utility of affective information as a compensatory mechanism for some older adults. Emotional enhancement of memory for words and faces has been found in older and younger adults, with the improved performance on positive as compared to negative stimuli slightly greater in older adults. Consistent effects of emotion on memory were found across the life span in a study of adults of varying ages, supporting the theory that emotions represent an area of strength of older adults. In some cases, however, emotional focus may have a negative effect on cognitive performance. In a study of recall based on an experimental play reading task, both older and younger adults were significantly less accurate in recalling aspects of the task when instructed to focus on affective content than those who were instructed to focus on factual content. To the extent that older adults are more likely in everyday situations to

focus on affective content, their memory performance may be negatively affected.

Theoretical Perspectives on Emotion in Older Adults

Research that derives from an explicit life span perspective of development and focuses on emotions is still relatively rare. One important exception to this general conclusion is the work on socioemotional selectivity theory (SST) by Carstensen and colleagues, which postulates that in late life, social interaction is increasingly more likely to be motivated by attempts to regulate emotion and increasingly less likely to be motivated by information-seeking goals. This in turn affects the type of social partners chosen by older people as well as the types of social interaction in which they engage. A wide array of evidence is available to support this proposition, including the fact that as social contacts decline with age, older persons are more likely to prefer familiar over unfamiliar social partners and are more likely to think about social partners in affective terms.

Another approach to considering the role of emotions in the context of development throughout the life course is articulated by Schulz and Heckhausen in their life span theory of control. They posit a motivation for primary control (i.e., having impact on the external world) as a major driving force in both survival and development. In this model, emotions serve as the fuel of a regulatory system whose major goal is to maximize the primary control potential of the organism. Both positive and negative affect generated through interactions with the environment have the potential of energizing the organism toward further primary control striving. Secondary control processes (i.e., having impact on the internal cognitive world of the individual) serve the function of protecting and enhancing primary control and are closely linked to emotions. An emotional response can instigate a secondary control process, which in turn promotes the motivational resources needed for primary control striving. Thus, the emotions system serves as a signal and as a motivational resource in shaping human behavior. This view is fundamentally different from SST in that it claims that emotions cannot be ends in themselves, although they may serve as proximal goals in specific situations. Another way of putting this is that maximizing primary control, rather than feeling good, is a major goal of human development. This view of the experience of emotions emphasizes their role as facilitators or mediators of primary control and is consistent with Nico Frijda's evolutionary perspective reflected in his statement that "the human mind (is not) made for happiness but instantiating the blind biological laws of survival" (1998: 354).

Future Directions

Because the majority of research on aging and emotions is cross-sectional, it is difficult to know whether observed differences between young and old reflect ontogenetic change or, alternatively, are primarily due to cohort or survivorship effects. Clearly, much more empirical work is needed in this area.

Psychosocial and physiological approaches indicate general patterns of normative emotional change with aging. While theoretical perspectives on the role of changes in emotions over the life span differ, the patterns of change in emotion indicate that there are significant differences in the experience, expression, and perception of emotion in late life. Clarification of the role of individual differences and age-related factors in producing emotional changes is important in determining the nature of aging of emotions. Ultimately, knowledge of emotional changes will be useful in developing interventions designed to improve the health and well-being of older adults.

See also: Gender Roles; Intelligence; Life Course; Life Satisfaction; Perception.

Further Reading

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Endocrine Function and Dysfunction

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Glossary

Androgens – Adrenal or gonadal hormones that enhance male sexual and reproductive function. Examples are testosterone, dihydrotestosterone, androstenedione, and dehydroepiandrosterone.

Estrogens – Gonadal hormones that enhance female sexual and reproductive function and that have widespread physiological effects in both females and males.

Glucocorticoids – Adrenal hormones, such as cortisol, with predominant effects on glucose homeostasis and cell-mediated immunity.

Insulin-like growth factor-1 (IGF-1) – A major mediator of growth hormone action.

Mineralocorticoids – Adrenal hormones with predominant effects on serum electrolyte metabolism.

Progesterone – Steroid hormone secreted by the adrenal gland and ovary.

Releasing Hormones – Hormones released by the hypothalamus to stimulate specific types of pituitary cells (e.g., TRH, CRF, GnRH, GHRH; see text for definitions).

Thyroid Hormones – Thyroxine (T_4) and triiodothyronine (T_3).

Tropic Hormones – Substances released by the pituitary gland to stimulate various target endocrine tissues. These include thyroid-stimulating hormone (TSH), adrenocorticotropic hormone (ACTH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), and growth hormone (GH).

Introduction

Altered cellular metabolism and intercellular signaling occur with advancing age, resulting in widespread changes in endocrine function. Aging is associated with both anatomic and secretory changes in the endocrine glands. Cellular responses within the hormone target organs also may change, including receptor binding, intracellular signaling, and gene expression responses. Hormone clearance rates and transport binding proteins may also be altered. Awareness of these changes is essential to the diagnosis and management of endocrine dysfunction in the elderly.

Overview of Hormonal Changes with Age

Altered cellular metabolism and intracellular and intercellular signaling with advancing age result in widespread changes in endocrine function. Several mechanisms interact in most systems to bring about the observed changes. Aging is associated with anatomic changes of the endocrine glands. In addition, with age, changes in hormone secretion occur, including alterations in circadian or seasonal biorhythms, changes in pulsatile frequency or amplitude of hormone secretion, as well as absolute changes in mean serum hormonal levels. The three main hormone systems that show decline with age are the gonadal hormones (menopause and andropause), the adrenal steroids DHEA and DHEA-S (adrenopause), and the GH/IGF-1 axis (somatopause).

Other changes occur in the cellular responses of target organs. Receptor binding and intracellular signaling reflect age-related alterations in plasma membrane properties, enzyme activities, and calcium mobilization. Gene expression, including translation efficiency, transcription rates, and DNA methylation, may show marked variations with age. Finally, changes in hormone clearance rates and binding to transport proteins contribute to the overall widespread changes observed.

The mode and mechanism of change vary with the hormone studied. In addition to intrinsic age-related changes in endocrine response, age-associated diseases, increased use of medications, changes in nutritional status, physical activity, and body composition also contribute to age-related endocrine dysfunction.

General Principles of Geriatric Endocrinology

The accurate diagnosis of endocrine dysfunction in the elderly requires a high index of suspicion. Signs and symptoms of hormone deficiency or excess may be absent. When such signs and symptoms are present, coexisting malnutrition or chronic disease may often make their interpretation difficult.

Hormone measurements and provocative tests must also be interpreted with respect to age. Some

hormones, such as luteinizing hormone (LH) and follicle-stimulating hormone (FSH), have clear gender-specific age-related changes. Others such as thyroid-stimulating hormone (TSH) show more subtle and variable alterations in what is considered normal with age. Provocative tests may give a blunted or altered response. Measurements of bound hormone may be less reliable due to alterations in serum proteins and hormone binding. Clearance rates are often affected by age due to changes in renal or hepatic metabolism, peripheral utilization, and even posttranslational changes in hormone processing.

Finally, therapy needs to be adjusted for age and coexisting disease. Potential side effects of therapies such as testosterone are increased and will affect the risk-to-benefit assessment of treatment and determination of optimal dose. Essential replacement, such as with thyroid hormone, should be initiated at a low dose and gradually increased to full dosage with careful monitoring of patient response and potential adverse reactions. With these precautions in mind, every effort should be made to diagnose and treat endocrine abnormalities even in the elderly debilitated patient, as this will improve quality of life. Generalized aging is intimately coupled with widespread progressive alterations in metabolism, of which changes in endocrine function are an integral part.

Anterior Pituitary

Age-Related Changes in Pituitary Function

Morphological changes are seen in the pituitary gland and fossa with aging. Chromophobe adenomas, especially prolactin producing, increase in incidence with age. They may be more difficult to diagnose, especially in females, because loss of menstrual cyclicity is the most common complaint of young women with prolactinemia, and this index is lost after menopause. In addition, many drugs commonly prescribed for the elderly, such as antidepressants, can secondarily increase prolactin levels into the range of microadenomas.

Aging is also associated with an increased incidence of anatomic and radiographic alterations in the sella turcica, including increased size and demineralization. Often no biochemical abnormalities are associated.

The peptide hormones of the anterior pituitary also change with age. A number of pituitary hormones exhibit altered patterns of secretion with advancing age, including growth hormone (GH), LH, FSH, adrenocorticotropic hormone (ACTH), and TSH. The circadian rhythms of plasma GH, prolactin, and melatonin are flattened.

There is a decrease in sleep-induced GH secretion, in peak amplitude, and in 24 h plasma levels of GH. Pituitary GH content remains unchanged with age. However, growth hormone releasing hormone (GHRH) receptors are reduced, and pituitary sensitivity to inhibition by somatostatin is increased. Both of these findings may lead to decreased release of stored GH.

There is also a decrease in the hepatic-systemic and local synthesis of insulin-like growth factor-1 (IGF-1) proteins. However, other factors, such as increased intra-abdominal fat mass and the presence of chronic illness, have a greater negative impact than advancing age and may exacerbate its effects.

The insulin-like growth factor binding protein-3 (IGFBP-3), which enhances IGF-1 action, also decreases, while IGFBP-1, which inhibits IGF-1 bioactivity, increases. An age-related decrease in basal and GHRH-stimulated GH secretion has been reported in male rhesus monkeys and rats. It has been postulated that in humans the decrease in GH action results in the muscle wasting and bone loss commonly seen with aging. GH and IGF-1 may play a role in learning and memory and have a neuroprotective effect in the aging brain. In aging rodents, GH treatment partially protects against ischemic brain injury. Higher plasma levels of IGF-1 are associated with better cognitive function in elderly human subjects. IGF-1 infusion improves cognitive performance in aging rats, and treatment with GHRH has been shown to improve cognition in the elderly. Low IGF-1 levels are associated with a high degree of cognitive impairment in Alzheimer's disease.

Serum prolactin levels decrease in females after menopause, whereas LH rises dramatically. Both pituitary content of LH and serum LH increase in intact animals. In human females, LH levels rise after menopause, in part because of decreased gonadal steroid feedback. However, the LH response to gonadotropin-releasing hormone (GnRH) actually decreases. Pituitary sensitivity to negative feedback by gonadal steroids may decrease, and conventional replacement therapy with estrogen in postmenopausal women fails to restore gonadotropin levels to premenopausal values.

In men, circulating prolactin levels are unchanged or increase slightly, while LH release decreases despite an increase in stored LH. This may be due in part to an increase in the sensitivity of gonadotropin-secreting cells to testosterone and dihydrotestosterone, which has been found in healthy older men and aging male rats.

The sex-specific changes in prolactin release may be secondary to changes in estrogen levels, which decrease with age in women and increase in aging men.

Aging is also associated with significant changes in LH pulsatile secretion. Age-related decreases in LH pulse frequency have been observed in human males and in male rats. Pulse amplitude is unaltered in humans but decreases in rats. Pituitary gonadotrophs isolated from old ovariectomized rats have a significantly lower LH content than young ovariectomized rats. LH beta mRNA is also decreased.

With increasing age, both stored and secreted FSH levels increase in both sexes. In older female rats the amplitude of FSH secretion on proestrus is less than 50% of the amplitude found in young rats.

TSH levels in the pituitary do not change with age, and circulating TSH is normal or slightly elevated. Diurnal variation is unchanged. Pituitary TSH sensitivity to thyrotropin-releasing hormone (TRH) and to changes in thyroid hormone concentrations decreases in the elderly. The age-related change in thyroid hormone sensitivity of the pituitary, along with decreased renal clearance of TSH, may result in elevated circulating TSH.

Age-related changes in GH, LH, and TSH may be secondary to changes in central nervous system (CNS) neurotransmitters and neuromodulators, including norepinephrine, serotonin, dopamine, β-endorphins, and enkephalins, which influence pituitary hormone secretion.

The corticotropin (ACTH) content may be slightly reduced in the pituitary with age, but basal ACTH secretion does not change. However, pituitary response to glucocorticoids shows a blunting of the negative feedback effects with age.

Pituitary Dynamic Testing

Although infrequently used, there are occasional indications for dynamic pituitary testing in the elderly. One should be aware of age-related changes in responsiveness, which are summarized in **Table 1**.

The ACTH response to corticotropic-releasing factor (CRF) or alternate stimuli is unchanged with age. TSH, prolactin, GH, LH, and FSH all show diminished stimulatory responses in dynamic testing in a significant proportion of individuals.

Growth Hormone Replacement

The systemic benefits of exogenous GH therapy in the healthy elderly remain unclear and controversial. Studies have not been able to demonstrate a clear anabolic effect of replacement of GH in elderly subjects, possibly because GH replacement cannot completely correct the alterations in binding proteins. Some studies have reported improvements in bone mineral density and muscle mass. Sarcopenia is related to increased tendency to fall, decrease in bone mineral density, decreased wound healing, and a decreased ability to maintain body temperature. Mechano growth factor (MGF) is a muscle-specific splice variant of IGF-1 that activates muscle stem cell proliferation, which is necessary for muscle regeneration. Treatment with exogenous GH plus resistance training has been shown to upregulate MGF in elderly muscle. Effects on muscle strength and quality of life have not been clearly documented. In addition, there is the concern that high normal serum IGF-1 may be associated with increased risk for breast and prostate cancers. Additional adverse effects include carpal tunnel syndrome, fluid retention, and decreased glucose tolerance. Endogenous overproduction of GH results in a decreased life span in mice and humans, and GH-deficient or -resistant mice exhibit a high level of resistance to oxidative stress and have increased longevity. Individuals with the A+ IGF-1 receptor gene polymorphism tend to have lower free IGF-1 levels, and these individuals are overrepresented in long-lived subjects. Therefore, it is still debatable whether long-term GH therapy will promote anti-aging or pro-aging effects.

GH may have a therapeutic role for short-term treatment of the frail elderly during acute illness, injury, or surgery. Several studies have shown acceleration of weight gain, an increase in muscle strength and endurance, and improved surgical recovery in malnourished or immobilized elderly patients.

Table 1 Age-related changes in anterior pituitary hormone response[a]

Hormone response	*Change*
ACTH response to CRF	N
ACTH response to insulin-induced hypoglycemia	N
ACTH response to intravenous metyrapone	N
TSH response to TRH in women	N
TSH response to TRH in men	↓
Prolactin response to TRH	↓
GH response to GHRH	N or ↓
GH response to insulin-induced hyperglycemia	↓
GH response to arginine infusion	N
GH response to levodopa	↓
LH and FSH response to GnRH	↓

[a] ACTH, adrenocorticotropic hormone; CRF, corticotropin-releasing factor; TSH, thyroid-stimulating hormone; TRH, thyrotropin-releasing hormone; GH, growth hormone; LH, luteinizing hormone; FSH, follicle-stimulating hormone; GnRH, gonadotropin-releasing hormone; N, no change; ↓, decrease.

Thyroid Gland Function and Dysfunction with Age

Thyroid Structure

There is an increased incidence of thyroid nodules with age. It is estimated that up to 90% of women over 70 years of age have thyroid nodules. Generalized changes may also occur, including increased fibrosis, flattened follicular epithelium, and increased colloid, as well as an increase in lymphocytic and plasma cell infiltration. In geographic areas of low iodine intake, the incidence of goiter increases markedly with age; up to 50% of the population may be affected.

Thyroid Hormone Economy

The metabolic response to thyroid hormones changes with age. Overall, there is a decreased response of the basal metabolic rate (BMR) to T_3 stimulation and a decrease in lipid peroxidation when corrected for caloric intake.

TSH secretory pulses exhibit reduced amplitude in normal elderly subjects, especially at night. Pulse frequency does not change. TSH bioactivity also decreases with age and may reflect age-related changes in glycation. In aging male Fischer 344 rats, immunoreactive serum TSH shows no change, but pituitary TSH-β subunit mRNA levels and TSH content decrease with age.

The TSH response to TRH is reduced in some groups of elderly men but is normal in others and in elderly women. This is apparently counterbalanced by an increased suppressibility of TSH by thyroid hormones in elderly humans. The ability of dexamethasone to suppress the TSH response to TRH is blunted in elderly men, suggesting that thyrotropes are also more resistant to glucocorticoids. This is of special interest because of the increased serum levels of glucocorticoids in response to several stimuli, which have been reported in elderly men due to age-related changes in the hypothalamus-pituitary-adrenal axis.

Thyroid gland responsiveness to TSH is not altered with age *in vivo*. The serum T_3 response to TRH-induced secretion of endogenous TSH is similar in young and elderly human subjects. However, a decrease in thyroid membrane high-affinity binding sites for TSH is observed in 24- to 26-month-old compared with 3- to 4-month-old rats. This is reflected in a decrease in TSH-stimulated adenyl cyclase activity in old rat thyroid membranes.

In rats, age-related decreases are seen in both TSH responsiveness to TRH and T_3 inhibition of the TSH response. T_4 declines with age, but this decline may be prevented by lifelong caloric restriction.

Several large studies in human subjects have documented no change in serum total T_4 and free T_4 during advanced aging in either males or females. Likewise, no change is seen in T_3 or reverse T_3 (rT_3) with increasing age. The changes in T_3 and rT_3 noted previously in elderly subjects may be a reflection of concurrent illness. Nutritional status may also affect these levels. Low caloric and carbohydrate intake correlate with elevations in rT_3.

The metabolic clearance of thyroid hormone decreases with age. The serum half-life of T_4 increases from a mean duration of 6.7 days in the third decade of life to a mean of 9.1 days by the seventh decade. Deiodination of both T_4 and T_3 is reduced. Sequential monodeiodination is also reduced. The decline in hepatic 5′-monodeiodinase activity may be due partly to decreased availability of reduced cofactor thiol groups, which decrease with maturation and aging.

The transport of thyroid hormone into brain and liver tissues is reduced in aged rats. T_3 transport across the plasma membrane is significantly reduced, while nuclear uptake remains unchanged.

Thyroid hormone action involves binding to specific DNA promoter and enhancer regions attenuating or augmenting the expression of specific genes. The encoded gene products include enzymes, transporters, harmones, and structural proteins.

T_3 stimulation of malic enzyme is reduced in aged rats. Malic enzyme mRNA is also reduced, suggesting a decrease in transcription rates or mRNA stability. Another enzyme that is stimulated by thyroid hormone is the Na^+/K^+-ATPase. Activity of this enzyme decreases with age in both renal cortex and liver. The enzyme may be partly responsible for the calorigenic effects of thyroid hormone; the decrease may contribute to age-related decline in thyroid hormone induced thermogenesis.

Cardiac relaxation slows with age. Ca^{2+}-ATPase activity and sarcoplasmic Ca^{2+}-ATPase gene expression are reduced in aged rats. The stimulatory effect of T_3 is also reduced. These changes may contribute to the age-associated slowing of relaxation. Aging and thyroid hormones also affect α- and β-myosin heavy chain (BMHC) gene expression. Both genes are highly expressed in neonates. The α-myosin heavy chain declines steadily with age and is stimulated by T_3. The effect of age on this T_3 response is unknown. BMHC also decreases after birth but rises again with aging. The effect of T_3 on this gene is decreased expression through binding to a negative response element in the gene encoding this isoform. With aging, the ability of T_3 to suppress BMHC is lost. The rat liver Spot 14 (S_{14}) gene encodes a small nuclear protein ($M_r = 17\ 010$) that regulates lipogenesis.

S_{14} gene expression increases with age. T_3 induces S_{14} gene expression; this response is blunted in older animals.

Thyroid Dysfunction: Clinical Aspects

Many clinical features of hypothyroidism are commonly found in the elderly, despite negligible changes in plasma thyroid hormone levels. These symptoms may reflect the decreased intracellular uptake of T_3 and alterations in gene activation/deactivation that are observed with aging.

On the other hand, numerous studies have shown a 3–4% incidence of unsuspected (subclinical) hypothyroidism in the elderly. Primary thyroid failure, usually secondary to chronic autoimmune thyroiditis, has been estimated to occur in 4.4% of the population over the age of 60 years. The prevalence of antithyroglobulin and antithyroperoxidase antibodies increases with age up to 70, then declines so that prevalence at age >100 years equals that found in controls <50 years. In one large study, 80% of elderly patients with high antithyroperoxidase antibody titers developed clinical hypothyroidism during a 4 year follow-up period. In contrast, elevated antithyroglobulin antibody titers do not appear to predict increased risk for hypothyroidism.

Hyperthyroidism is more difficult to diagnose in the elderly due to lack of classical clinical signs. Symptoms of hyperthyroidism, especially those secondary to increased adrenergic activity, are frequently blunted in older individuals. The reduced signs of adrenergic hyperactivity in elderly hyperthyroid patients may be the result of age-related desensitization of β-adrenergic receptors. The heart rate response is reduced in elderly subjects regardless of thyroid status. Low serum TSH is more common in the older patient, most often accomplished by a normal serum T_4 concentration. In one large study, 6 out of 50 elderly patients with low TSH became hyperthyroid during 4 years of follow-up.

Some of the effects of hyperthyroidism may be totally different in elderly individuals. Weight loss secondary to hyperthyroid status occurs in both young and older individuals. However, the etiologic pathway may be different. As many as 36% of elderly patients with hyperthyroidism experience anorexia. Using pair fed rats, weight loss in hyperthyroid older rats has been linked directly to decreased food intake in the aged rats compared with their younger counterparts.

A high index of suspicion, appropriate laboratory testing, and careful slow replacement of thyroid hormone when required will greatly facilitate the care of the elderly patient with thyroid disease.

Adrenal Gland Function and Disease with Age

Adrenal Cortex Structure

Structural changes take place in the human adrenal cortex with age. Gland weight declines slightly with age, and the cortex undergoes degenerative changes, including increased fibrosis, accumulation of lipofuchsin, epithelial cell dropout, mitochondrial fragmentation, and vascular dilation and hemorrhages. Cellular depletion is observed in the zona reticularis. An increased incidence of adrenal adenomas has been found on autopsy. Up to 50% of adrenal glands from aged subjects show small cortical nodules.

Adrenal Physiology

Hypothalamic CRF content does not change in rats or humans as a function of age, but baseline and stimulated infundibular portal CRF levels are increased in the rat. This increase may reflect the observed increase with age in a subpopulation of CRF neurons that also contain arginine vasopressin (AVP) and that are selectively activated by stress.

Glucocorticoids Aging of the hypothalamic-pituitary-adrenal (HPA) axis is highly species dependent. In aging dogs, ACTH and cortisol levels show hyperresponsiveness to CRF or stress. In aging rats, the ability to secrete ACTH and corticosterone in response to CRF or stress is reduced, but baseline levels of these two hormones are elevated. In male Fischer 344 rats, the pulse amplitude of pituitary ACTH secretion is decreased. Pituitary CRF receptor concentrations are significantly decreased without alterations in ligand affinity.

In humans, the pituitary ACTH response to exogenous CRF or to intravenous metyrapone does not change. However, a diminished sensitivity of pituitary ACTH to negative feedback by cortisol is suggested by several findings. Dexamethasone suppression of ACTH has a higher false positive rate; this is further exacerbated by coexisting dementia of Alzheimer's disease. Exercise endurance training also alters the suppressive effect of dexamethasone on cortisol and ACTH secretion in response to CRF, making it less effective.

Moreover, the increased cortisol response to CRF with normal levels of ACTH suggests decreased negative feedback with or without increased adrenal stimulation of cortisol secretion by ACTH. Challenges that alter CNS feedback to the HPA axis, such as trauma, physostigmine, or naloxone, tend to show a greater cortisol response in older subjects. Older subjects show a delayed recovery to baseline cortisol

levels following CRF or ACTH challenge post-surgery. The elderly have higher serum cortisol in response to depression or to perioperative stress than young subjects.

The limbic system modulates the HPA axis. In rats, aging is associated with selective loss of corticosterone binding neurons and glucocorticoid receptor (GR) mRNA in the CA3 hippocampal zone. Also with age, hippocampal inhibition of ACTH release is attenuated.

Hippocampal neurons have both mineralocorticoid receptors (MRs) and GRs. MRs and GRs may mediate coordinate but antagonistic effects on excitability by hippocampal neurons. In rats and dogs, limbic system MR binding capacity is markedly decreased with aging, whereas GRs are unchanged, altering the homeostatic balance and leading to HPA hyperreactivity during senescence.

Glucocorticoid target tissues also show age-related change. The affinity of hepatic cytosolic steroid receptors to dexamethasone and corticosterone is significantly reduced in aged rats, although receptor number does not change. Stimulation of tyrosine aminotransferase, a corticosteroid-induced enzyme, decreases with age. Impaired glucocorticoid receptor activation may be responsible for the decrease.

Changes in the HPA axis may also lead to altered immune function, including reduced tumor surveillance, with aging. Natural killer cell activity shows an age-related decrement both at baseline and in response to CRF in rats.

The adrenal gland may directly mediate the age-related reduction in stress tolerance. Restraint-induced expression of heat shock protein 70 (hsp70) in rat adrenal cortex declines throughout the life span of the rat. Hypophysectomy negates the hsp70 response, and ACTH replacement restores it, indicating a role for hsp70 in the physiological stress response.

There is evidence that persons exposed to elevated cortisol levels due to Cushing's syndrome or exogenous glucocorticoid therapy show a number of cognitive and physical impairments normally associated with aging. Age-related losses of adrenal steroid receptors have been hypothesized to result from cumulative exposure to glucocorticoids themselves. Administration of exogenous glucocorticoids or chronic stress accelerates hippocampal pathology, whereas adrenalectomy reduces it. Memory deficits, atherosclerosis, muscle weakness, osteoporosis, immune dysfunction, and cerebral atrophy have all been associated with excess levels of glucocorticoids. Exposure to chronic stress with its associated elevations in ACTH and cortisol may have similar consequences, and stress and aging may act synergistically to exacerbate each other.

Adrenal disorders are not common in the elderly. The three most prevalent ones are adrenal mass, glucocorticoid excess, and adrenal insufficiency. As in younger patients, a functioning adrenal mass is most likely a pheochromocytoma or aldosteronoma that can be evaluated by abdominal imaging and urinary measurements of catecholamines and their metabolites. Serum potassium should also be measured. Most tumors are non-functioning. Those that are functional and those greater than 4 cm or that are rapidly enlarging should be removed if the patient can tolerate surgery.

For evaluation of cortisol excess, 24 h urine free cortisol should be measured. If ACTH is also elevated, a tumor secreting ectopic ACTH is the most likely cause in this age group.

Acute adrenal insufficiency is rare; it usually occurs in the setting of severe acute illness. The elderly are more susceptible, especially in the setting of acute myocardial infarction, sepsis, or anticoagulation. Adrenal gland metastatic disease or tuberculosis can also cause adrenal insufficiency. A negative ACTH stimulation test will confirm the diagnosis, but this should be deferred if the patient is in acute adrenal collapse. The decreased clearance rate of cortisol may result in a decreased replacement dosage requirement of hydrocortisone or cortisone in the elderly.

Adrenal Androgens Plasma levels of dehydroepiandrosterone (DHEA) and DHEA sulfate (DHEA-S), the principal C19 steroids produced in the human adrenal, decline to less than 20% of their maximal value by age 60 in both women and men. This may reflect the decrease in size of the zona reticularis that is observed with aging and a concomitant decrease in cytochrome b_5, an accessory protein that stimulates DHEA synthesis.

Postmenopausal women compared with young cycling women have decreased product and precursor ratios for DHEA/17-hydroxypregnenolone and for androstenedione/17-hydroxyprogesterone, suggesting a reduction in 17,20-desmolase with age. The reductions in androstenedione are probably due to reduced ovarian secretion after menopause. In cows, p450 c17 mRNA and induction by ACTH are reduced with aging. In human males, DHEA secretion declines progressively between 20 and 96 years of age. Older men have serum levels that are 5–30% of levels seen in younger men. The age-related reduction in secretion rate of adrenal androgen in both men and women is reflected in reduced urinary 17-ketosteroid excretion.

In rodents, DHEA has antihypercholesterolemic, antiatherosclerotic, and antihyperglycemic effects. In

humans, age-associated decreases in adrenal androgen production may contribute to decreased immune function, osteoporosis, and atherosclerosis. Cognitive ability and bone mass density may also be affected. As noted previously, in contrast to the decline seen in DHEA and DHEA-S, production of cortisol remains fairly constant with age. This may further contribute to decreased immune function and increased susceptibility to infection, as DHEA has stimulatory effects on immune function while cortisol has some inhibitory effects, especially at very high levels, such as those associated with trauma or severe illness.

Prospective observational data suggest that low DHEA and DHEA-S can predict ischemic heart disease. However, randomized, placebo-controlled clinical trials in individuals age 60 years and over treated with 50–100 mg/day of DHEA have yielded very few favorable effects on mood, well-being, cognitive and sexual functions, bone mass, body composition, vascular risk factors, immune functions, or skin. The major limitations of these trials were their short duration (maximum 1 year) and the low number of study participants involved (maximum 280).

Widespread DHEA replacement in the elderly can not be recommended. However, subjects with adrenal insufficiency may benefit from DHEA replacement therapy. In one study, DHEA replacement in women with adrenal insufficiency decreased symptoms of depression and anxiety and improved alertness, mood, and sexual function. DHEA replacement did not change body mass index (BMI), waist-to-hip ratio, fat mass, lean mass, BMR, exercise capacity, insulin, or glucose.

Mineralocorticoids Aldrosterone secretion decreases with age, most likely secondary to a reduction in plasma renin activity (PRA), by about 50%. The reduction in aldosterone secretion is evident both at baseline and after salt restriction or standing or in response to ACTH. The aldosterone clearance rate also decreases with age, by about 20%. This may partially offset the decreased baseline secretion. However, the elderly are more prone to postural hypotension and dehydration. This is due, at least in part, to the decreased mineralocorticoid homeostatic response. Other contributing mechanisms are discussed in the later section on water balance.

Adrenal Medulla

In rats the adrenal medulla becomes hyperplastic with hypertrophy of individual chromaffin cells with age.

Secretion rates of epinephrine and norepinephrine (NE) from the adrenal gland under resting conditions in the rat increase two- to fourfold between the ages of 100 and 800–900 days. Aging also increases the plasma catecholamine response to stress in aged rats. Serum baseline NE but not epinephrine is elevated in 24- versus 3-month-old Fischer 344 animals. CRF-stimulated catecholamines are also elevated.

In addition, tyrosine hydroxylase (TH) activity and TH-mRNA are elevated in old rats compared with young ones. Exercise conditioning decreases both TH activity and mRNA in young but not old rats, suggesting that sympathoadrenal plasticity diminishes with age.

In humans, plasma NE may increase with age in the general population. This is accompanied by a decrease in platelet α2-adrenergic receptors and cardiac β-adrenergic transmission, implying down-regulation with age in the presence of elevated NE. Dopamine levels do not change. Others have found that NE levels do not increase in non-smokers between the ages of 25 and 65 years. However, elevated levels of both epinephrine and NE were found in healthy octogenarians compared with healthy 24- to 28-year-olds. Catecholamine excretion has been shown to decrease in those between 60 and 80 years of age. Smoking significantly elevates catecholamine levels and excretion.

The NE response to upright posture, tilt-table test, insulin-tolerance test, cold-pressor test, or glucose ingestion is increased in the elderly, whereas both the epinephrine and NE response to exercise at 75% maximal work load is decreased in healthy elderly male subjects as compared to their younger counterparts.

The Reproductive System

Male Reproductive System

In human males, reproductive system aging occurs at both gonadal and CNS levels. Primary changes in testicular function include decreased sperm production and testosterone (T) secretion. Impairment in Leydig cell function occurs with age, with a decrease in production of pregnenolone, the substrate for T synthesis. Plasma total T levels are below normal, defined as 250 ng/dL, in 7% of men age 40–60, 20% of men age 60–80, and 35% of men age >80. Sex hormone binding globulin (SHBG) also increases, reducing the bioavailable and free T.

Anatomic changes in the testes include thickening of the basement membrane of seminiferous tubules and thinning of the germinal epithelium, increased peritubular fibrosis, and germ cell arrest. The number of Sertoli cells is reduced, and both basal and induced inhibin-B levels decline as early as

the fifth decade. There is a decline in daily sperm production. Although grossly normal areas of spermatogenesis are usually preserved until late in life, there is evidence for an age-related increase in sex chromosome aneuploidies in human sperm. Chromosome breaks and point mutations increase exponentially with age in germ cells of human males, and there is a fourfold increase in total chromosomal structural abnormalities by age 45. Reduced T levels, resulting in diminished DNA topoisomerase II α activity with increased age, may increase the frequency of chromosomal non-disjunction or breakage.

The decrease in serum T may be secondary to both primary testicular failure and decreased LH secretion from the pituitary. Compared to young men, in healthy older men LH pulse frequency may be reduced. In the anterior pituitary of aged male Brown Norway rats, GnRH receptors show a significant decrease. This plus an age-related decrease in pituitary calcium second messenger mobilization may be responsible for the reduced LH. Finally, the gonadotropin-suppressing activity of T or dihydrotestosterone is increased in healthy elderly men and in aging male rats.

In contrast, FSH is elevated, reflecting decreased testicular functions, including sperm production and inhibin secretion by the Sertoli cells. Clomiphene citrate stimulates gonadotropin levels in elderly men, but both LH and FSH increase less in elderly men than in young men. Elderly men also show a smaller rise in total T, bioavailable T, and 17β-estradiol (E_2), indicative of a significantly diminished testicular response. Circulating activin increases with age, but its effect on reproduction is not clear.

Complex changes in steroid metabolism occur with aging. The metabolic clearance rates of both T and dihydrotestosterone are reduced. T reduction to 5β-metabolites is increased. There is also an increase in conversion of T to E_2. This, coupled with the fact that E_2 clearance is also reduced, leads to an increase in the E_2/T ratio in older men.

Age-related changes also take place in tissue uptake of sex steroids. Androgen receptor concentrations in the hypothalamus and pituitary, the testes, and the ventral and lateral prostate are reduced with age in the rat; receptor affinity in brain and prostate is also reduced. Expression of hepatic androgen receptors decreases, leading to a decrease in $\alpha 2\mu$ globulin mRNA, a biomarker of androgen action in liver.

Aging in men is associated with increased fat; insulin resistance; falls and fractures; decreased muscle mass and strength, physical performance and activity, and bone mineral density (BMD) and libido; and anemia. It is not recommended that all elderly men be treated with androgen therapy. However, clinical features of androgen deficiency may warrant replacement. These consist of lethargy, fatigability, decreased libido, depressive mood, tiredness, decreased muscle and bone mass, increased visceral fat, impotence, and cognitive impairment plus total $T < 200$ ng/dl. Testosterone therapy can increase BMD in hip and lumbar spine. Whether T increases cardiovascular risk is debatable, since epidemiological associations relate low, rather than high, T concentrations to cardiovascular morbidity and T may actually lower LDL.

Female Reproductive System

In contrast to the gradual onset of the male climacteric, menopause in the female is a more dramatic event. Cessation of menses is, however, the result of slowly progressive changes in ovarian and hypothalamic-pituitary function. The loss of inhibin restraint of FSH appears to be the initiating event that leads to menstrual cycle shortening and some of the hormonal dysregulation of the late reproductive years. Circulating activin increases with age, but its effect on reproduction is not clear. The median age for menopause in the United States is currently 51 years. But even prior to menopause, fertility declines with age. The conception rate at age 30–34 is only 73% of that seen between ages 20 and 24, i.e., 63% vs. 86% incidence of pregnancy after 12 months of unprotected intercourse. By age 40 the conception rate is only 50%. There is also a significant age-dependent decrease in embryo survival, which correlates with ovarian age.

The number of oocytes in the mammalian ovary declines with age. In the human ovary few follicles remain at the time of menopause. However, studies in mice reveal that dividing germ cells are present in the adult ovary, challenging the long-held concept that ovarian senescence is inevitable. Sclerotic changes occur in the medullar portion of the aging ovary. Hypophysectomy or food restriction, which is associated with low gonadotropin levels, prolongs the reproductive potential of animals.

There is a gradual reduction in ovarian response to pituitary gonadotropins beginning 2–5 years prior to menopause. Ovarian secretion of E_2 and progesterone decreases gradually, and suppression of gonadotropins by estrogen is reduced. The final cessation of cyclic ovarian function leads to markedly decreased estrogen following menopause. LH and FSH levels increase markedly. In addition, pituitary LH release in response to GnRH agonists is significantly reduced in aged female mice, and in older female rats the amplitude of FSH pulses is 50% of that found in younger rats.

Decline in the number of ovarian follicles leads to a decrease in inhibin levels. Circulating activin also increases with age. Alterations in inhibin/activin tone may perturb osteoblast and osteoclast development and uncouple bone formation from resorption. This may increase bone turnover even prior to the early menopausal transition when inhibin-B declines but serum E_2 is conserved.

The effects of declining estrogen include genital tract atrophy, impaired autonomic vascular tone, and loss of bone density. E_2 is a dominant regulator of GH secretion. IGF-1 declines in perimenopausal women and the IGF-1/IGFBP-3 ratio drops, reducing bioavailable levels of IGF-1.

Uterine changes occur secondary to altered ovarian hormones as well as altered uterine responsiveness to hypothalamic, pituitary, and ovarian hormones and may contribute to a decrease in fecundity with age. Both estrogen receptor numbers and nuclear binding of estrogen receptors are decreased in the aged rodent uterus. Progesterone receptors do not change.

In contrast to the marked decline in ovarian estrogen secretion, ovarian adrenal androgen secretion and peripheral steroid conversion continue. As a result, the normal premenopausal estrogen to androgen and estrone to estradiol ratios are inverted.

In the rat model of reproductive aging, changes are not seen in the number of GnRH-producing cells with age, and isolated hypothalami do not exhibit altered GnRH secretion. However, *in vivo* GnRH secretion may be reduced. The basic biochemical phenomena responsible for this change in secretion probably occur both within the GnRH-producing neurons and in response to altered cell–cell interactions. Several changes in gene expression occur within the GnRH neuron. Expression of galanin, a brain-gut peptide that colocalizes to a subpopulation of GnRH neurons, is markedly reduced in these cells in aged animals. Expression is linked to estrogen-progesterone levels, implying that the relative concentrations of these two hormones modulate age-related changes in GnRH neuron physiology.

In the CNS, *c-fos* acts as a transcription factor that activates a number of genes, including GnRH. In middle-aged female rats, expression of this gene in the hypothalamus during proestrus is markedly reduced compared with younger animals. Inputs from higher CNS neuroendocrine responsive centers may be indirectly responsible for the altered GnRH response with age in the intact animal. Widespread changes in dopaminergic and cholinergic neurons occur with aging, including areas such as the amygdala and hippocampus, which are involved in higher CNS regulation of reproductive and sexual function.

Proliferative changes in the ovarian epithelium, such as papillomatous outgrowths, are more common in the postmenopausal ovary. Up to one-third of postmenopausal women have stromal hyperplasia. In a small proportion of these patients, excess androgen production causes virilization. Ovarian thecomas occur most commonly in the sixth decade of life and can secrete estrogen or androgens. Estrogenizing thecomas can be associated with endometrial carcinoma. Lipid cell tumors of the ovary also typically occur in older women. Androstrenedione secretion by these tumors can cause virilization.

Estrogen Therapy

Age-related decline in ovarian function leads to decreased circulating levels of gonadal hormones, including E_2 and progesterone. Related signs and symptoms include irregular menstrual cycles with eventual loss of cycles, vasomotor instability, changes in hair, skin, and mucous membranes, cognitive and affective changes, decreased bone mineralization, urogenital dysfunction, changes in libido and sexual function, sleep disturbances, and headaches. After menopause, women also exhibit weight gain, decreased glucose tolerance, and an increased incidence of cardiovascular disease, including hypertension, and cerebral and myocardial ischemia.

Modern hormone therapy in the United States dates back to 1929. It has been estimated that between 1970 and 2002, approximately one-third of eligible women elected to use hormone therapy. Standard hormone therapy consists of a daily dose of estrogen, with progesterone added for women with an intact uterus, to prevent the development of endometrial dysplasia caused by unopposed estrogen. There are numerous options for route of administration of hormone therapy, as well as chemical form and dosage. These should be individually tailored based upon the desired therapeutic effects and potential risk factors. Reports of increased breast cancer risk and adverse cardiovascular events related to use of estrogens and progestogens by postmenopausal women have called into question the risk–benefit assessment of sex hormone therapy. This subject is highly controversial.

At menopause, women's risk for cardiovascular disease, osteoporosis, and glucose intolerance rises significantly and substantially. Estrogen therapies have clearly been shown to improve mood, cognition, sleep, vasomotor stability, and bone density. While prolonged estrogen exposure appears to increase the number of breast cancers detected, the overall risk of mortality from the disease is not increased.

Estrogen may also have a protective effect against the development of Alzheimer's disease (AD). The relative rate of AD in women using estrogen compared with non-users was 0.46 in one large study of 472 women followed for 16 years. Another study showed that women's sex-specific increase in risk for AD disappeared after 10 years of estrogen therapy. Advances in the early detection of AD, including imaging studies of brain metabolism and measurement of serum amyloid peptides, may better help to identify patients likely to benefit from estrogen therapy. Once dementia is established, however, estrogen may have no effect or may even accelerate dementia.

More than 20 observational studies with hormonal therapy in postmenopausal women have also reported a 30–50% reduction in the incidence of coronary artery disease. Estrogen reduces oxidation of LDL cholesterol and angiographic evidence of coronary disease. However, several randomized trials, including the Heart and Estrogen/Progestin Replacement Study (HERS) and Women's Health Initiative (WHI), failed to show a cardioprotective effect. Comparison of the randomized trials to earlier studies reveals significant differences in the patient characteristics. Patients in the observational studies were younger and healthier and had a lower average body weight. They were also experiencing menopausal symptoms.

Timing of hormonal therapy appears to be an important factor, as both women and non-human primates initiating therapy close to the time of loss of ovarian function show a reduction in cardiovascular events, while older women with established cardiovascular disease exhibit a small increase in vascular complications. This statement is further supported by the fact that analysis of a younger subset of patients with vasomotor instability from the WHI trial did not show an increase in vascular complications. Clear demonstration of the potential cardioprotective effects of estrogen may depend upon the timing of therapeutic intervention (perimenopause vs. long-standing hormone deficiency) and the exclusion for comorbidities including smoking and obesity. Further consideration needs to be given to the development of therapies that will retain the benefits and decrease the risks of treatment.

Female Androgen Deficiency Syndrome (FADS)

The prevalence of sexual dysfunction in women approaches 43%, and age is an important correlate. The underlying etiology of sexual dysfunction in women is complex. Nevertheless, hormonal changes such as loss of estrogens and androgens contribute significantly to some of the sexual difficulties experienced by aging women.

In women, direct ovarian production accounts for half the circulating T, while the other half is produced through peripheral conversion from adrenal precursors. Both ovary and adrenal gland contribute equally to circulating androstenedione, while 90% of DHEA is produced by the adrenal gland. Oophorectomy in premenopausal women reduces T and androstenedione levels by 50%, while in menopause, T changes minimally and androstenedione decreases by 50%. Total T, free T, and androstenedione are lower in women with central hypoadrenalism and hypogonadism secondary to hypopituitarism than in subjects with hypoadrenalism or hypogonadism alone.

Female androgen deficiency (FAD) is diagnosed when there are clinical symptoms, decreased bioavailable T, and normal estrogen status. The potential causes of FAD include diseases of ovary, adrenal gland, or hypothalamic-pituitary unit, or drug-related or idiopathic causes.

Optimal treatment of FAD is being investigated. Interventional trials with DHEA have shown limited effects in select populations such as those with adrenal insufficiency. T replacement therapy has been utilized in few double blind randomized trials. Improvements in sexual desire, vasomotor symptoms, and mood have been documented. However, potential side effects such as acne, hirsutism, deepening of the voice, and possibly increased cardiovascular or breast cancer risk are of concern.

The exact interplay between the estrogens and androgens as to sexual activity is not known, and the correlation between specific serum hormone levels and sexual activity is not always consistent. Controlled trials of estrogen and/or T therapy in FAD have shown an improvement in sexual function among natural or surgically menopausal women. However, long-term safety of hormonal therapy, optimal types, doses, and routes of therapy are not currently established.

Calcium and Bone Metabolism

Age-Related Changes in Physiology

The most common age-related histologic change in the parathyroid glands is an increase in the number of oxyphil cells and an increased incidence of oxyphil cell nodules. In young adults, bone resorption and formation are in balance so that bone mass remains constant. This equilibrium is altered by gonadal failure and aging in general, leading to a relative increase in bone resorption, bone loss, and osteoporosis.

Non-genetic age-related causes of bone loss with aging are multiple. These include decreased sex

hormone production, decreased vitamin D activation, and increased secretion of parathormone (PTH), decreased intestinal uptake of calcium and protein, decreased osteoblast activity, and decreased physical activity.

PTH secretion increases without a change in clearance, resulting in increased serum PTH in aged rats and in humans older than age 65. This is believed to be a compensatory change in response to reduced production of 1,25-dihydroxyvitamin D and reduced intestinal calcium absorption. Up to 90% of long-term care elderly patients have subnormal serum levels of 1,25-dihydroxyvitamin D, and many have elevated serum PTH levels. However, healthy elderly subjects may have normal levels of serum 25-hydroxyvitamin D and 1,25-dihydroxyvitamin D. Serum levels of 1,25-dihydroxyvitamin D, the most active form of vitamin D, have been reported to either decrease or remain unchanged in both men and women. Bone levels in women decrease after the age of 45. A decrease in the synthesis of 1,25-dihydroxyvitamin D occurs with aging. There is a decrease in 1α-hydroxylase in the kidney, which results in decreased conversion of 25-hydroxycholecalciferol to 1,25-dihydroxycholecalciferol. This is probably related to reduced responsiveness of the kidney 1α-hydroxylase to PTH.

Serum osteocalcin, a marker of osteoblast activity, may be normal or decreased in elderly humans in the setting of increased PTH. This suggests osteoblast resistance to PTH resulting in decreased bone formation and turnover.

Elderly women have a higher maximal PTH response to EDTA-induced hypocalcemia compared to young women. They also have a greater non-suppressible component of PTH secretion without a change in set point. Therapy with 1,25-dihydroxyvitamin D reverses the abnormal PTH secretory dynamics. Estrogen therapy will also attenuate the plasma PTH levels in elderly women.

Age-related impairment of renal function may falsely elevate immunoassayable levels of PTH due to decreased clearance of PTH metabolites. This problem has been largely circumvented by use of the two-site PTH immunoradiometric assay.

In aged rats, serum osteocalcin is decreased. Paradoxically, in rats, long-term ovariectomy increases bone osteocalcin mRNA. The significance of this finding is unclear. PTH levels also rise in aging rats. However, the set point for PTH release increases in aged male Fischer 344 rats. In aged rats, ionized calcium and 1,25-dihydroxyvitamin D levels fail to increase in response to PTH, indicating that both kidney and skeleton may show reduced response to PTH with aging. Aging reduces intestinal and skeletal receptors for 1,25-dihydroxyvitamin D in rats. Treatment with 1,25-dihydroxyvitamin D partially reverses the decrease in intestinal receptors. Vitamin D replacement also improves oral calcium absorption. In aged rabbits, the renal response to PTH is blunted. There is a decrease in the stimulatory effect via cAMP on the Ca^{2+}/Mg^{2+}-ATPase. This may lead to decreased calcium reabsorption and increased urinary calcium loss.

Calcium availability is decreased in the elderly because of decreased dietary uptake and synthesis of vitamin D, which contributes to decreased intestinal calcium absorption. Over 40% of adults over 50 years of age may be vitamin D deficient. For most adults, 5–10 minutes of direct sun or UVB exposure daily can offset this deficiency. Vitamin D deficiency contributes to calcium imbalance and can cause osteomalacia and muscle weakness. Vitamin D deficiency has also been associated with increased risk for cancer and cardiovascular disease. Surveillance for vitamin D deficiency should be done by yearly monitoring of 25-hydroxyvitamin D.

Intestinal absorption of calcium decreases with age, especially after age 70. Intestinal calcium uptake decreases in senescent rats as a result of decreased stimulation by 1,25-dihydroxyvitamin D and a decline in calcium transport proteins. GH and PTH act synergistically to increase intestinal absorption of calcium in aged female rats. IGF-1 increases Ca^{2+} transport across human intestinal cells *in vitro* independent of 1,25-hydroxyvitamin D and may mediate the effect of GH. Thus, this defect in intestinal transport may result, at least in part, from the decreased GH levels that are seen in aging. In addition, IGF-1 levels in femoral cortical bone have been shown to decrease in both men and women between the third and sixth decade of life. This may affect calcium transport into bone. Calcium imbalance in the elderly leads to increases in PTH and increased phosphate diuresis. PTH binds to specific receptors on osteoblasts, upregulating RANK-L (receptor for activation of nuclear factor-κB ligand) expression and downregulating osteoprotegrin (OPG). This leads to increased differentiation of osteoclasts and bone resorption.

Aging also affects calcitonin (CT) secretion in female rats. In old but not young rats, ovariectomy causes an increase in basal and Ca-stimulated CT levels. Estradiol reduces the plasma CT in response to hypercalcemia in old ovariectomized rats.

With increasing age, pluripotent mesenchymal cells present in bone marrow decrease differentiation into osteoblasts and chondrocytes and reciprocally increase differentiation into adipocytes. Therapeutic strategies to prevent bone loss may target factors that regulate progenitor cell fate.

Osteopenia

Skeletal development is maximal in healthy individuals at age 25 in women and at age 30–35 in men. Bone changes occur during normal aging in both men and women. These changes include alterations in the dynamics of bone cell populations, uncoupling bone formation and resorption, changes in bone architecture, accumulation of microfractures, and changes in mineralization and in the protein matrix. Aging also induces a decrease in skeletal mass. Osteopenia is defined as clinically significant bone loss. In addition to loss of bone mass, osteoporosis is accompanied by bone pain, spinal deformity, loss of height, and an increased incidence of fractures. In healthy males, radial bone mineral content (BMC) decreases by 1% per year between 30 and 87 years of age, whereas vertebral BMC decreases by 2.3% per year. Treatment with calcium carbonate and cholecalciferol for 3 years does not prevent the decrease in subjects with a high basal dietary calcium intake (>1100 mg/day). In addition, between the ages of 35 and 70 cortical bone strength in bending is decreased by 15–20%, and cancellous bone strength in compression is reduced by about 50%. Bone becomes increasingly brittle and fractures with less energy.

Susceptibility to clinically significant osteopenia is affected by many variables including genetics, nutritional status, body mass, exercise, and peak bone mass. Hormonal deficiency such as GH may contribute to lower than normal peak bone mass. Diabetes may be an additional risk factor for development of osteopenia. In rats, both aging and type 1 diabetes result in increased collagen-linked fluorescence in bone, a measure of non-enzymatic cross-links, which is correlated with decreased bone density, decreased serum osteocalcin, and increased bone fragility. Osteopenia can in part be prevented from progressing to osteoporosis by maintaining good nutritional status (protein, calcium, vitamin D) and adequate physical activity.

Gonadal steroid effects on bone may be sex specific. During development the bone metabolic response to gonadal hormones becomes gender dependent on androgens in males and on estrogens in females. Androgen deficiency causes osteopenia in aging male rats. This can be reversed by treatment with T, 5α-dihydrotestosterone, or E_2.

In aged ovariectomized rats, treatment with E_2 prevents loss of spinal bone mineral content. Calcitonin is less effective. However, N-terminal human PTH alone or in combination with E_2 or calcitonin increases BMC to sham-operated levels and increases mechanical strength. This is of special interest because E_2 treatment in oophorectomized women increases intestinal calcium absorption independent of 1,25-dihydroxyvitamin D, prevents BMC loss, and increases serum calcitonin levels. At least one large study has shown that bone mineral density in postmenopausal women can be maintained by estrogen replacement into the ninth decade of life.

Treatment with oral calcium and vitamin D is also effective. Treatment with 800 IU/day of vitamin D decreased the fracture rate in a group of French nursing home patients. Other studies using 1,25-dihydroxyvitamin D have shown improved calcium absorption and BMC with a significant decrease in fracture rates.

First-line treatments for both men and women with primary osteoporosis are calcium and vitamin D supplementation and alendrolate therapy. Other approved therapies include gonadal steroids, if deficient, and recombinant PTH or calcitonin.

Carbohydrate Metabolism in the Elderly

A decline in glucose tolerance with age is a common finding that leads to an increased incidence of type 2 diabetes (T2DM) in the elderly. If we define diabetes by an oral glucose tolerance test value greater than 200 mg/dl at 2 h with at least one additional value also above 200, then the percentage of affected males in the United States rises steadily from 5% at age 25 to over 30% at age 85. By age 60, 18.3% of persons have diabetes. Nearly 50% of individuals with T2DM are over the age of 65 years.

Elderly persons have reduced insulin sensitivity and impaired insulin-mediated glucose uptake in peripheral tissues, especially skeletal muscle. Impaired insulin action with age is not generally accompanied by change in insulin membrane receptors in target cells. Decreased target cell membrane insertion of the insulin-sensitive glucose transporter GLUT-4 may be responsible for the defect. Exercise in middle-aged subjects with T2DM has been shown to elevate levels of GLUT-4 in skeletal muscle and improve glucose tolerance. Exercise in elderly men has been shown to increase the resting metabolic rate and possibly decrease circulating insulin levels and insulin-to-glucose ratios, implying an increase in insulin sensitivity. These differences are inversely related to the percent body fat composition of subjects.

The pancreatic islets show an increased sensitivity to inhibition of insulin release by somatostatin. In rats, the impaired secretion is increased by treatment of islets with somatostatin antibodies. The insulin-to-glucose ratio is usually decreased, suggesting relative islet cell resistance to glucose-stimulated insulin release. The last phenomenon may be related in part to reduced islet cell adenyl cyclase activity.

The insulin clearance rate decreases modestly from a half-life of 11 min in the young to 13 min in the elderly. Glucagon clearance is not changed, and plasma levels of glucagon do not change with age in humans. In rats, secretion of glucagon from pancreatic islets increases with aging. The age-related change in glucagon secretion may be secondary to altered glucose homeostasis or to reduced pancreatic α-cell responsiveness to glucose or paracrine regulatory factors. In the elderly, the lipolytic and ketogenic but not the hyperglycemic responses to pulsatile glucacon are significantly reduced.

The prevalence of diabetic complications, including retinopathy, nephropathy, and neuropathy, increases with the duration of diabetes. Aging may accelerate the onset of complications due to synergistic effects of aging and diabetes on cellular metabolism. Both aging and diabetes can cause oxidative imbalance, leading to increased production of reactive oxygen species (ROS) and reactive nitrogen species (RNS). Increased ROS and RNS are associated with increased damage to DNA and impaired protein function.

Advanced glycation end products (AGEs) form spontaneously from glucose-derived Amadori products and accumulate on long-lived tissue protein. AGEs have been implicated in the pathophysiology of both aging and diabetes.

Pentosidine, a glycation reaction product found in skin and glomerular basement membrane, increases with age. Levels are further elevated above the 95% confidence limit in 80% of diabetics, both type 1 and type 2, compared with age-related non-diabetic controls.

Vibratory perception and thermal discrimination decrease with both age and diabetes. Autonomic distinction is also compromised by both factors. Both T1DM and T2DM patients develop superior mesenteric ganglioneuronal lesions prematurely and in greater numbers than non-diabetics.

A number of age-related coexisting disorders may complicate the management of diabetes in the elderly. These include hypodipsia, anorexia, visual impairment, impaired baroreceptor response, depression, altered renal or hepatic function, and multiple medications. Reduced thirst perception and polypharmacy increase the risk of hyperglycemic hyperosmolar coma. The elderly are more prone to hypoglycemia from use of sulfonylureas but may also have a more varied response to insulin. Variations in response to insulin with exercise are also heightened in the elderly. Dietary management may be more difficult, and exercise regimens should be tailored individually according to coexisting physical limitations such as organic heart disease.

In normal aging, the pancreas shows loss of compact structure of islets with hyalinization, increased amyloid deposition, and increased incidence of tumors, especially islet cell tumors. Hyalinization is found in almost 50% of diabetic patients over the age of 60. Islet amyloid polypeptide (IAPP or amylin) is co-secreted with insulin from the pancreatic β-cells. Amyloid deposits, which are associated with increased β-cell death and reduced β-cell mass, are present in the pancreatic islets of approximately 60% of elderly diabetic subjects. Most islet cell tumors, especially glucagonomas and somatostatinomas, are diagnosed in the fifth through seventh decades of life.

Water Metabolism in the Elderly

Multiple interrelated changes in water and electrolyte homeostasis occur with aging (**Table 2**). Elderly subjects show unusual thirst following dehydration, heat stress, or hypertonic saline infusion. There is a change in perception of thirst, possibly a deficit in the opioid-sensitive drinking drive, mediated through oropharyngeal receptors. Naloxone administration decreases fluid intake in young but not old subjects after overnight fluid deprivation; older subjects have a lower rehydration intake after placebo as well.

AVP secretion from the pituitary gland responds to salt (osmoreceptor) and fluid status (baroreceptor). Baseline AVP secretion in healthy elderly, both supine and ambulatory, may not differ from healthy young subjects when there is no age-related difference in serum osmolarity. However, some studies have shown an increase in baseline AVP with age. This may be a compensatory mechanism reacting to a decrease in vasopressin receptor sensitivity in the kidney. There is a rise in AVP following dehydration in both young and old. However, the lowest level of plasma osmolality that will initiate AVP secretion (osmotic threshold) is reduced in the elderly. In addition, the rehydration decrease in AVP found in young subjects is not seen in the elderly.

Table 2 Age-related changes in water and salt homeostasis[a]

Parameter	*Change*
Thirst	↓
AVP, baseline	↑ or no change
AVP, after dehydration	↑ (reduced threshold)
Renal response to AVP	↓
Renin-angiotensin	↓
ANP	↑
Renal response to ANP	↓ or no change
Aldosterone responsiveness	↓ (2°↓PRA)
Baroreflex sensitivity	↓

[a] AVP, arginine vasopressin; ANP, atrial natriuretic peptide; PRA, plasma renin activity; ↓, decrease; ↑, increase.

Older subjects also show a reduced AVP response to volume-pressure change with relative renal resistance to AVP. The decreased response may be due to changes in AVP receptors in the kidney. Decreased cyclic AMP (cAMP) generation in response to AVP is involved in the age-related impairment of urinary concentrating ability. This may predispose the elderly to dehydration when intercurrent illness causes increased water loss or limited access to water.

Another important physiological stimulus of AVP secretion is angiotensin II. With aging, plasma renin activity is decreased along with a reduction in angiotensin-converting enzyme activity. Thus, the elderly have a reduced capacity for generating angiotensin II, a potent stimulator of AVP secretion and thirst. Hypoangiotensinemia has been implicated as the pathogenetic mechanism of dehydration in a group of hypernatremic elderly patients.

Approximately 3% of elderly subjects develop nocturnal polyuria syndrome (NPS), characterized by deterioration of the 24 h rhythm of AVP, in which secretion is normally higher at night. AVP levels are very low or undetectable and may be lower at night than daytime. NPS is characterized by nocturia and sleep loss. It can be treated by avoidance of excessive fluid intake, dosing of any diuretic medications in the afternoon, and oral desmopressin at bedtime.

Aging is associated with a decreased ability to excrete salt and water, thus increasing susceptibility to volume overload in elderly individuals. Atrial natriuretic peptide (ANP) is secreted in response to volume expansion and has both diuretic and natriuretic actions. Baseline ANP has been found to be elevated in elderly humans and aged rats. The normal decrease in ANP following dehydration is blunted in the elderly. The source of increased ANP appears to be increased cardiac peptide synthesis, as mRNA levels and immunoreactive peptide are both increased in the left ventricle of aged rats. Young subjects exhibit a significant circadian rhythm for ANP, which elderly subjects do not have.

The effects of aging on ANP action in the kidney are controversial. A 2 h low-dose ANP analog infusion in one group of healthy elderly men failed to elicit the expected change in blood pressure or renal salt excretion, despite an increase in urinary cyclic guanosine monophosphate (cGMP). Others have found the natriuretic effect of native ANP to be preserved in aging despite a diminished renal hemodynamic response. Renal blood flow decreases and renal vascular resistance increases in young but not old subjects after a 2 h peptide infusion.

ANP suppresses vasopressin release and raises the threshold of vasopressin release in response to osmotic stimulation in both young and elderly individuals. High baseline circulating ANP levels may be in part responsible for the observed decrease in plasma renin activity (PRA). PRA is decreased up to 50% in the elderly, and reduction in PRA is probably the main cause of the decreased aldosterone responsiveness observed in the elderly.

See also: Diabetes; DNA and Gene Expression; Glycation; Homeostasis and body regulation; Menopause; Metabolism: Carbohydrate, Lipid and Protein; Neurotransmitters and Neurotrophic Factors; Osteoporosis and Aging Related Bone Disorders; Thirst and Hydration.

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Environmental Gerontology

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Glossary

Environment – According to Lawton, the objective physical environment refers to all that lies outside the skin, that is inanimate, and that is measurable in centimeters, grams, or seconds. The subjective environment addresses the gamut of processes operating when aging individuals form cognitive and affective ties to their physical–spatial environments.

Environmental Attributes – Attributes characterizing the environment, the most important of which are safety, accessibility, orientation, privacy, and control.

Environmental Functions – As Lawton suggests, the different functions that environments can serve as people age, including maintenance, support, and stimulation.

Person–Environment Fit – The basic assumption that diverse aging outcomes are linked to different person–environment constellations, characterized by differential person and environmental attributes. The better personal attributes fit with environmental attributes, the better the expected outcome.

Introduction

Aging always occurs in a context. Environmental gerontology, as a major area within the wide array of aging research, places special emphasis on deriving an in-depth understanding of the interrelations between aging persons and their environments and how these relationships shape aging outcomes. The overarching aim of environmental gerontology is thus to describe, explain, and modify or optimize the relationship between the aging person and his or her sociophysical environment, a task accomplished within an interdisciplinary framework. Given that persons with declining competencies are especially vulnerable to their environments, a particular focus of environmental gerontology has been on person–environmental attributes such as safety, accessibility, orientation, privacy, autonomy, and personal control

among the very old and individuals with a high prevalence of physical and cognitive impairments and chronic illnesses. Nevertheless, the scope of environmental gerontology is expansive and considers aging processes within environmental contexts across the continuum of wellness, from the highly competent to the very frail. A range of theories has been suggested to address both the objective and subjective processes of aging individuals interacting in their environments. Theories considering the objective dimension of person–environment relations have primarily focused on level and type of competencies of aging individuals in relation to design characteristics and the press or demands of physical environments. Other theories have posited a range of psychosocial processes by which aging individuals form cognitive and affective connections and how these in turn affect health and well-being. Looking ahead, designing and optimizing environments for older people is one of the most critical societal tasks in view of the dramatic changes in the age structure throughout the world and the important role of the environment in supporting, promoting, and sustaining life quality. Because of this, aging research on person–environment relations will probably grow in importance in the future.

Mission and Ambition of Environmental Gerontology

Environmental gerontology strives to understand the role of the sociophysical environment in the maintenance and improvement of autonomy and well-being of aging individuals and, specifically, the relationship of persons to their environments, and its utilization and optimization. While environmental gerontology primarily considers the relevance of the full range of physical components of the environment for aging processes, also acknowledged is the strong, integrated role of the social environment, hence the term sociophysical. For example, the home environment is not only a physical structure, but also a place punctuated by pronounced intimacy with one's partner, social interactions, and the symbolization of attachment, normalcy, and loss. Thus, the term environment as used in environmental gerontology predominantly refers to the physical environment, but also acknowledges its interwoven nature with social and cultural accoutrements and implications. Moreover, environmental gerontology is founded in the basic principle that old age is a critical phase in the life course that can be characterized as being profoundly influenced by the sociophysical environment. That is, as people age, place matters more, and, importantly, it matters differentially based principally on a person's sociocultural background, somatic and psychic health, and cognitive and physical functional abilities.

Since aging had long been considered as a process driven chiefly by a genetic and biological program inherent in the organism, the explicit consideration of the sociophysical environment and how the aging process unfolds or manifests in different contexts was an important step in the historical development of gerontology. This paradigm shift, from viewing aging strictly from a physiological perspective to a more complex vision of its environmental expression, was mainly driven by the growing role of a social and behavioral scientific stance within gerontology beginning in the 1930s. In addition to considering biological and health changes or personality characteristics per se, it was also assumed that aging is strongly influenced by variables such as social relations, housing, neighborhood conditions, and urban or rural settings.

The overarching aim of environmental gerontology is to describe, explain, and modify or optimize the relationship between the aging person and his or her sociophysical environment. Environmental gerontology places a strong emphasis on day-to-day contexts of aging individuals, reinforcing the notion that this everyday world in natural settings deserves the full attention of gerontological research. A prototypical issue is that older people spend most time in their home environment, and as a consequence, housing characteristics, as the major setting in which aging unfolds, has been a major focus of research in environmental gerontology from its inception.

The task of explanation basically relies on German psychologist Kurt Lewin's fundamental definition of the life space as a function of the person and his or her environment ($B = f(P\ E)$). American environmental gerontologist M. Powell Lawton suggested an addition to the ecological equation ($B = f(P\ E\ P \times E)$) to account for the influence of person–environment interactions. This interaction term suggests that person-related competencies and needs operate or manifest differently in different environments and lead to dissimilar outcomes. For instance, having low or high mobility competence may not affect the autonomy of an individual to obtain a goal such as ascending stairs if an escalator is also available. However, if an escalator is not available, the autonomy of the low-mobility person may be highly threatened, whereas there may be no effect on autonomy for the person with high mobility.

The focus on modification and optimization reflects the aspiration of environmental gerontology to have a substantial and direct contribution to the improvement of quality of life in old age. Prototypical is the involvement of environmental gerontology

in advancing evidence-driven home modifications or the design of public spaces with the goal of enhancing autonomy and well-being as people age.

Given the broad array of goals of environmental gerontology, it is not surprising that it is founded upon and nurtured by a diversity of scholarly inputs, and that an interdisciplinary approach – covering disciplines such as psychology, sociology, architecture, social geography, occupational therapy, urban planning, health and social policy, technology, and design – is essential. As a consequence, overlap with other major research and practice areas in gerontology such as housing, institutional aging, or gerontechnology is obvious and necessary.

The Aging Person and the Environment – General Considerations

Although the interaction between aging individuals and their environments is a fundamental tenet of environmental gerontology, it remains helpful to consider basic issues specific to the person and the environment separately.

The Aging Person's Competencies and Needs as Related to the Environment

Considerations on the societal, demographic, and individual level provide an important backdrop for research pursuits in environmental gerontology. The number of people aged 65 or older will soon reach 20% of the American population, a number similar to many other developed countries. In addition, older people are the most diverse of all age groups, thus pointing to pronounced heterogeneity in lifestyles, needs, and preferences. Of equal importance is that the fastest growing segment of the older population continues to be the 85 and older group. Concomitantly, the number of persons who care for a family member steadily increases. Currently, one out of every three persons is or will be a caregiver of a loved one.

The implications of these trends for person–environment research are manifold. First, given the prominence of housing as the major day-to-day context of aging, research related to the potential and constraints of the home environment is an important avenue to preserving health and quality of life in later life. Designing and optimizing environments for the full heterogeneity of aging persons are among the most critical areas of research as well as societal challenges in the future. Second, the oldest old are at higher risk of requiring personal assistance, living alone, having a lower income, being socially isolated, living in homes in need of repair, and living in neighborhoods with a tendency toward decline. The link between environment and health is therefore particularly powerful for the oldest old, who also are at greater risk for chronic diseases and functional vulnerabilities that impact everyday living. In other words, the everyday difficulties imposed by age-related diseases such as mobility problems, sensory loss, or cognitive impairment significantly shape the dynamics of persons and environments; this is particularly true for very old people with varying degrees of functional abilities. A related point is that the home environment is rapidly evolving into the primary context in which medical, rehabilitative, and palliative care is provided. Third, independent of existing vulnerabilities and frailty, there has been and continues to be a strong desire of old and very old people to age in place, or remain in their familiar home environment or an environment of their choice for as long as possible and feasible for themselves and their family members. This desire may ultimately reflect an optimization strategy critical to late life that affords continuance and control over important aspects of daily life, including routines, self-care, and other potentially meaningful and self-defining activities. Seen from this perspective, person–environment considerations are critical to understanding the meaning of the good life in old age and the potential and limitations of private and professional caregiver arrangements.

Environmental Characteristics as Related to the Aging Person

Due to the emphasis in environmental gerontology on the physical environment, a definition of the environment is necessary and should specifically focus on this aspect of the life space. According to Lawton, the objective physical environment covers all that lies outside the skin, that is inanimate, and that is measurable in centimeters, grams, or seconds. A full set of empirical findings underscores how objective features of environments influence aging on a variety of levels. For example, older people who live in high-rise buildings or on higher floors report less satisfaction with their housing and tend to leave their homes less frequently. Distance to public transportation or green areas shapes the outdoor mobility and social interaction patterns of older people. Of equal importance is how the objective environment is subjectively experienced in affective and cognitive terms and personal meanings. How functional changes are experienced can be quite diverse in aging individuals faced with similar objective environmental conditions.

Empirical research has also underscored the importance of considering the role of the subjective experience of environments on an older person's behavior. For example, even very poor housing quality is associated with relatively high residential satisfaction and attachment to place and may not necessarily be a motivating factor for relocation. The use of outside environments may be shaped by feelings of safety and security that may or may not be justified based on objective crime rates or other objective safety characteristics.

A variety of attributes have been suggested as characterizing any type of environment. Safety of the environment is among the most important prerequisite for users. Accessibility of the environment is of vital importance to the participation in society by all citizens, but particularly old and disabled persons. Accessibility can be assessed based on existing norms and guidelines, aimed at ensuring that a majority of members of a given society (ideally all) are able to use environments independent of competence status. Orientation addresses the potential of the environment to guide navigation or way-finding. For example, nursing home environments can be designed to support way-finding even for persons with impaired cognitive capacity. Privacy refers to the possibility provided by the environment to retreat and have a place of pronounced and undisturbed personal intimacy. This is another prototypical challenge of institutional aging, but can also become an issue in private housing when pronounced personal care needs infuse small shared spaces. Control of environmental conditions addresses the possibility of exerting self-directed changes and achieving personal needs or life goals.

Additionally, environments can be categorized according to their different functions in promoting quality of life. Again, Lawton has made a convincing suggestion for a tripartite, overarching general classification scheme. First, environments can have a supportive function in compensating for lost competencies as people age. Second, environments can stimulate daily life, for example, by the experience of novelty caused by a new item in the home environment or by strolling in an attractive park area. Third, environments have a maintaining function; that is, they add to the aging person's striving for continuity and meaning. Seen from a life course perspective, the stimulating function of the environment can be expected to be more important for the young old, while the supportive and maintaining functions become increasingly critical as people pass from old to very old age.

A final consideration of environments has to do with different levels of analysis of person–environment interactions. On one hand, at the micro-level, it is important to focus on the aging person in his or her concrete home environment. At the macro-level, research driven by the urban–rural distinction and housing policies is important for the understanding of person–place relations as people age.

Understanding Person–Environment Relations as People Age: Major Conceptions and Findings

The in-depth understanding of person–environment processes and outcomes has so far not been achieved by one major theory; rather, a multitude of conceptual approaches that augment and build on each other in a pluralistic manner infuse the field.

Objective Approaches to Person–Environment Relations

One major assumption of person–environment relations is the environmental docility hypothesis, initially proposed by Lawton and Simon in 1968 and refined and graphically expressed in 1973 by Lawton and Nahemow's competence-environmental press model (**Figure 1**).

The competence-environmental press model provides a broad, overarching framework that allows different types and levels of competence such as sensory loss, physical mobility loss, and cognitive decline and environmental factors including housing standards, neighborhood conditions, and public transport to be considered. Perhaps the most important element of the competence–press model is its fundamental assumption that for each aging person there is an optimal combination of (still) available competence and environmental circumstances leading to the relative highest possible behavioral and emotional functioning for that person. A term frequently used for this in environmental gerontology is person–environment fit. The model also suggests that it is at the lower levels of competence that older people become the most susceptible to their environment, such that low competence in conjunction with high environmental press negatively impacts an individual's autonomy, affect, and well-being. A related point is that as competencies decline, the zone of adaptation narrows, such that environmental choices that can promote well-being become increasingly more limited although there is always an option. The competence–environmental press framework continues to provide the basic mechanism of person–environment relations as people age and has been supported by a considerable body of empirical

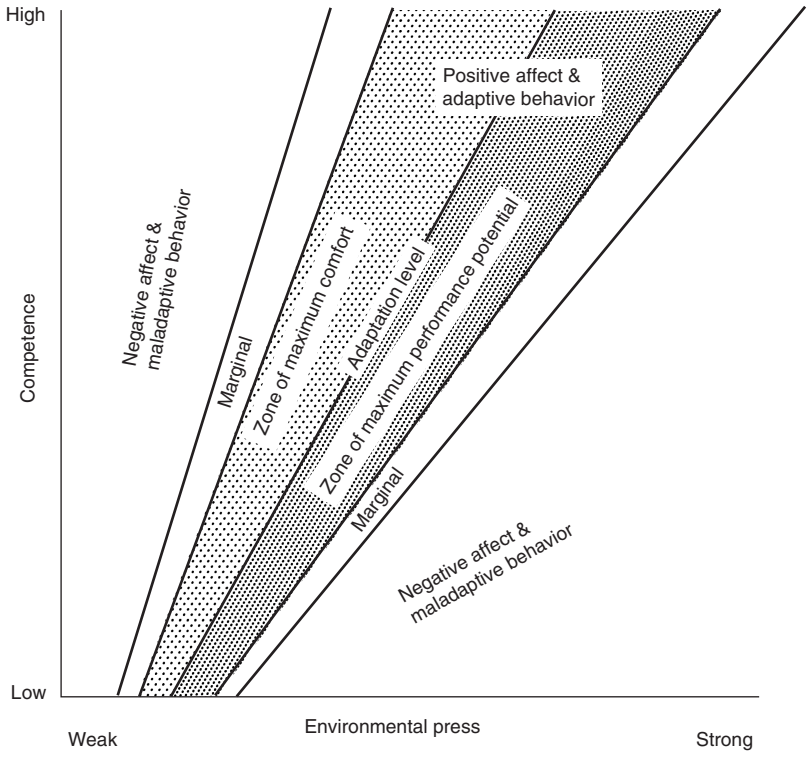

Figure 1 The competence-environmental press model as originally suggested by Lawton and Nahemow (1973). Redrawn from Lawton MP and Nahemow L (1973) Ecology and the aging process. In: Eisdorfer C and Lawton MP (eds.) *The Psychology of Adult Development and Aging*, pp. 132–160. Washington, DC: American Psychology Association. with permission of American Psychological Association.

research. For example, research on the impact of physical distances on social interaction patterns of elders in institutional settings shows that longer distances undermine social relations, thus highlighting the environmental docility as people age. Furthermore, the competence–press model has become a major driver in the practical world of designing and optimizing environments for older people.

In addition to putting emphasis on competence as is done in the competence–press model, other conceptions of person–environment fit as suggested by Carp and Kahana underscore the role of motivation in person–environment relations. The basic assumption is that misfits between given needs and given environmental options to fulfill these needs are linked with lowered behavioral functioning and well-being. Empirical support for this assumption has been reported by studies conducted in institutional settings as well as private home environments. For example, remaining autonomy in visually impaired elders was found to depend on how much the physical layout of home environments adds to the compensation of the vision loss. Furthermore, a distinction between an older person's basic versus higher-order needs has been suggested. Basic needs are related to basic issues of maintaining competence (e.g., maintaining independent self-care), while higher-order needs address issues such as privacy and affiliation. While person–environment misfit in the basic need domain predominantly results in reduced behavioral autonomy, misfit in the higher-order need realm may also undermine emotional well-being and mental health.

Social ecology concepts suggested by scholars such as Baltes assume close links between physical environments and the social behavior of persons acting in these settings. Institutions have formed an ideal arena for social ecology approaches, driven by the assumption that a behavioral setting in which care professionals regularly interact with residents has major consequences for their autonomy in the longer run. The empirical application of this model has produced profound insights into the role of the social environment in dependent behavior of nursing home residents by repeatedly identifying robust interaction patterns characterized as a dependence support script. According to this interaction script, staff tend to overly support or encourage dependent behaviors of residents, while independent behaviors are mostly overlooked.

The person–environment stress model argues that objective environmental conditions such as a lack of accessibility, privacy, or control in one's environment may provide the source for stress experiences. For instance, aging individuals may feel a psychological threat, apathy, reduced well-being, or depression as a consequence of such a stress experience. This model can be applied to family caregiving as well. For example, difficult to manage dementia-related behaviors and lack of control over daily routines reflect the objective environmental conditions that typically confront families of persons with dementia. These environmental stressors over and above subjective appraisals of the care situation may affect a caregiver and result in significant stress, anxiety, or depression.

Finally, relocation may be seen as the most radical alteration in person–place relations. The understanding of residential decisions and their outcomes in old age has attracted environmental gerontology from early on in the development of the field. Early research in the 1960s and 1970s provided by scholars such as Coffman was mainly driven by the relocation trauma hypothesis, in which mostly negative health effects of moving in later life were assumed. Relocation to an institutional setting was the prototypical case for applying the relocation trauma hypothesis. The empirical evidence, however, remained controversial and was plagued by methodological problems such as selectivity of study samples, overinclusion of the frail, and lack of control groups. Litwak and Longino suggested in 1987 a distinction between first, second, and third moves by relying on the assumption of a substantial association between chronological age and type and motivation of move. Whereas first moves often take place early in the aging process, i.e., close to retirement, and are usually prompted by the amenities associated with the desired place of residence, second moves, occurring in the 70s and early 80s, are predominantly characterized by moving back to the place of origin, reflecting a higher need for support and proximity to kinship. Third moves are often relocations to institutions due to frailties that are not compensable by family resources in very old age. As has been found in more recent research, relocation is driven in current cohorts of older people by a variety of motivations, among which higher-order needs such as access to participation in social, cultural, and educational opportunities appear to become increasingly important. A primary example is the so-called sunbelt movers, that is, the movement of mostly young old people to places better serving their needs in terms of climatic conditions and/or surrounding communities, as is found in so-called sun cities.

Subjective Approaches to Person–Environment Relations

In contrast to the foregoing approaches pointing mostly to the role of the objective environment, the gamut of processes operating when aging individuals form cognitive and affective ties to their physical-spatial environments has also found important conceptual and empirical consideration.

The classic approach addressing the cognitive-affective relation to the physical environment is reflected in the construct of housing satisfaction. As has consistently been found, elders, both healthy and frail, tend to score high in measures related to this construct, regardless of their objective home and neighborhood conditions. This has been coined the housing satisfaction paradox. A common explanation is that anticipating a move may be psychologically threatening for many older people. Thus, enhancing the evaluation of one's environmental quality becomes the only option to reduce the resulting cognitive dissonance of living in worsening conditions without being able to relocate.

In addition to residential satisfaction, which has been measured primarily in a unidimensional manner based on a single question, sophisticated approaches have emerged to provide a more nuanced understanding of the subjective world of aging in place. One widely acknowledged approach suggested by Rowles in 1983 has focused on the many faces of what he has coined insideness. According to Rowles, different types of insideness that speak to the transition of spaces into places can be empirically derived. Whereas social insideness arises from everyday social exchanges over long periods of time, physical insideness is characterized by familiarities and routines within given settings such as the home environment. A third element of insideness has been labeled autobiographical insideness, that is, places that carry a rich collection of memories and thus support the aging individual's sense of place identity. Empirical research has also shown that physical insideness is particularly important for aging individuals with chronically disabling conditions.

Rubinstein's conception of the meaning of home relies on the assumption that the active management of the environment in itself represents a major source of well-being as people age, especially for those who are frail or living alone. Rubinstein identifies three classes of psychosocial processes that give meaning to the home environment: (1) social-centered processes, ordering of the home environment based on a person's version of sociocultural rules for domestic order, (2) person-centered processes, expression of one's life course in features of the home, and

(3) body-centered processes, the ongoing relationship of the body to the environmental features that surround it.

Furthermore, place attachment has been defined as reflecting feelings about a geographic location and emotional binding of a person to places. As has been empirically found, place attachment seems to steadily grow across the life course, reaching its culminating point in very old age. This also underscores the point that forced relocation in very old age (third moves, particularly to institutions) due to a chronically disabling condition is a critical life event and a profound challenge for maintaining well-being and a sense of identity.

The Disablement Process and the Environment

The environment has a very specific and critical role in the disablement process. Despite variations in models of disablement, a similar process is proposed such that a pathway or trajectory from pathology (a disease state) to distinct but related and measurable consequences occurs. Specifically, pathology, defined as an interruption or interference of normal physiological and developmental processes, is viewed as resulting in neurological or physiological deficits, the basic consequence of which is impairment. Impairment, defined as an abnormality at the organ level (cognitive, motor perception, sensory or psychological function), may in turn impact or lead to a functional limitation. Functional limitations refer to restrictions in performing basic physical and mental actions. Physical actions may include mobility (e.g., walking), stooping, reaching, grasping, or sensory issues (e.g., trouble hearing, seeing, or communicating), whereas mental actions refer to cognitive and emotional functions (e.g., short-term memory, orientation in time and space, or affect). In turn, the impaired ability to perform such basic actions may lead to disability. Disability refers to having difficulty performing essential activities of daily life including basic and instrumental care, social recreational participation, and socialization. As such, disability may reflect a gap between a person's capability, the demands of a particular task, and the social and physical environment.

Verbrugge and Jette's widely acknowledged iteration of the disablement process dating from 1994 suggests two related notions of competency related to the environment: an individual's ability regardless of context, which is referred to as intrinsic ability, and an individual's ability as supported or constrained by the person's physical and social environment, referred to as actual disability. The implication is that the interaction between a person's intrinsic abilities and the built environment, including both its physical and social characteristics, yields actual disability. Thus, one conclusion is that disability is an outcome of potentially modifiable environmental factors and can therefore be minimized. Although Verbrugge and Jette's model does not articulate the specific pathways between human behavior and the physical environment, it provides a framework for such linkages to be examined and underscores that objective conditions (e.g., presence of external supports, home modification) may offset further disablement independently of and/or in conjunction with personal appraisals and social resources.

Approaching Person–Environment Relations on the Macro-Level of Analysis

The aforementioned approaches predominantly consider person–environment interactions on the micro-level of analysis; that is, the focus is on obtaining an in-depth understanding of the role of the immediate environment within which people age. However, as Bronfenbrenner's ecological theory of human development and other social science approaches suggest, in targeting person–environment relations, the micro-environmental level is undoubtedly influenced and shaped by macro-level environmental contexts, including the neighborhood at large, housing policies, economic standards, cultural values and beliefs, and social and long-term care service provision and policies. These factors all form the environmental context of aging with varying immediate and distal impacts on the everyday life of people as they age. The quality of neighborhood settings may strongly impact the physical range and timing of out-of-home activities as people age. An important consideration is the life course perspective. It could well be that persons initially live in high-quality neighborhoods that subsequently decline over time, placing people in the later years of their life at a disadvantage. Another classic research question is the urban–rural distinction and how this affects aging. For example, use of the outside environment may depend on public transportation possibilities, which may be more underdeveloped in rural than urban regions. On the other hand, the macro-level perspective also considers the diversity in cultural norms, and disadvantages in person–environment options in rural areas could be compensated for because of stronger intergenerational ties and higher prevalence of cohabitation of older and younger family members. Still, the consideration of person–environment interrelations is worth considering across countries, i.e., as a cross-cultural research

challenge. For example, the definition of barrier-free environments and respective legislative norms and regulations probably depends on the economic situation as well as on different cultural conceptions of autonomy and the role of physical environments compared to social environments such as the family system.

The Need for an Integrative View

There is no one theoretical accounting or approach that best captures the many facets and complexities of person–environment interrelations and that has driven empirical research in the field thus far. The heuristic fruitfulness of using the full family of concepts, theories, and analytic levels can be seen as follows. First, different concepts and theories point to the gamut of essential elements of environmental resources critical for quality of life in old age. In particular, the objective environment is more relevant for outcomes such as autonomous day-to-day functioning, whereas cognitive and affective bonding to the environment is related more to well-being, identity, and meaning as people age. It is, however, important to also address the linkages between objective and subjective person–place relations. Second, there is the need to consider the interrelatedness of different environments: home and outdoors, micro- and macro-environmental levels. It is reasonable to assume that a balanced view of behavior as shaped by the home environment as well as by out-of-home settings serves the purpose of understanding outcomes such as well-being or participation in the community and society at large. Third, physical and social environments, as echoed in the term socio-physical environments, must be seen as closely intertwined, each augmenting or unfolding with the other. The classic example is the strong impact of physical distance or barriers on social interaction patterns in old people. This basic insight still deserves more research based on a balanced view of the physical and social environment. Fourth, person–environment research is a strong driver of interdisciplinary aging research, requiring and enabling an integration of perspectives and disciplines as diverse as psychology, geriatrics, and architecture.

Outlook and Future Challenges

Person–environment interrelations are a major prerequisite for aging well. Given the steadily growing portion of older people with all their diversity in terms of cultural enactments, competence, needs, life situations, and living environments, environmental gerontology research and its application are closely linked to the challenges of aging societies now and in the future. Looking forward at forthcoming cohorts of older people, the dynamics of changing person–environment relations implicitly drives the aging policy debates. The home environments of the old and very old will become increasingly heterogeneous, and the classic distinction between community-residing and institutionalized most likely will not be sustained, with institutions becoming more home-like and homes assuming more functions of medical and social care. In addition, it is predicted that technology will assume a major role in the home and away, strengthening the potential for future aging in place for individuals with varying ranges of competency. As a consequence of these highly likely trends, environmental gerontology research will enter new territory, such as the interlinkages between traditional environments and new technology. Also, the role of virtual reality as a historically new person–environment interaction mode has increasing importance for persons as they age; the outcome of this remains to be seen in future environmental gerontology studies.

See also: Adaptation; Dementia; Gerontechnology; Housing; Human Factors and Ergonomics; Mobility and Flexibility.

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Epidemiology

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Glossary

Active Life Expectancy – The average number of years a member of a population may expect to live free of chronic disability.

Atherogenesis – The physiological process by which atherosclerotic plaques start and grow within an organism's circulatory system.

Carcinogenesis – The physiological processes leading to loss of growth control by cells in particular tissue systems that lead to the development of malignant cell clones or tumors.

Censoring – The systematic loss of cases in a study due to processes relevant to the study goals.

Compression of Mortality – Implies that there is a biologically fixed upper bound to the human life span near enough to a population's current life expectancy that further mortality reductions will be constrained by that limit.

Mortality Selection – The systematic loss of persons from a population due to high mortality risks being associated with specific characteristics under study.

Observation Plan – The logical structure under which data are collected to describe specific processes or event dynamics with particular characteristics.

Oldest-Old – An extremely elderly population often characterized by high rates of comorbidity and chronic disability. This group is often defined as persons either 85 and older or 95 and older.

Osteoporosis – The loss of bone mineral density, usually at later ages, and more often in postmenopausal females, due to hormonal changes.

Plasticity of Aging – The concept that the outcomes of biological processes underlying senescence and age-related health changes may be altered by exogenous factors.

Introduction

Epidemiology is the study of the causes and manifestations of disease in either free-living or experimentally

selected populations. Epidemiological methods, concepts, and data vary greatly with the specific diseases and population groups studied. For example, there are well-established epidemiological methods for the study of tropical diseases due to parasites and very different methods for examining the emergence of chronic diseases in developed country populations. This article considers a relatively new area of study, i.e., the epidemiology of aging.

Definition and Concepts

Epidemiology is the study of the effects of diseases on populations, their health and longevity, and the factors causing, and agents transmitting, disease. Classically, epidemiology was the study of disease caused by infectious organisms (i.e., the study of 'epidemics') – the rapid rise in disease incidence in a population due to a common exposure to a pathogen (or environmental toxin). Implicit in the classical concept was that there were 'host' factors determining the susceptibility of an organism to an exposure, commonly termed a pathogen (for a biological agent such as a parasite, bacteria, or virus) or an environmental hazard (for physical agents such as lead or asbestos exposure), which were transmitted to susceptible members of a population by an agent (e.g., mosquitoes for malaria or yellow fever; infected hypodermic needles for AIDS) often called the disease vector.

These and other epidemiological concepts are often modified in studying aging and chronic disease. Chronic disease epidemiology deals with disease processes, often with lengthy latency periods between exposure and disease manifestation with long natural histories of manifest, and evolving health consequences for the host. Many physiological mechanisms determining chronic disease progression involve more complex interactions, over longer periods of time, between the natural history of the disease and the physiological characteristics of the host than in infectious diseases. For example, both atherogenesis and carcinogenesis, after being triggered by exposures, could be manifest in self-sustaining 'pathological' physiological processes in the host. Interest has emerged in what has been termed 'frailty.' This is described by a general system dynamic underlying the failure of multiple organ systems that involves degradation in a number of basic metabolic parameters. This would define a relatively new type of health construct for epidemiologists in that the primary disease mechanisms are time-related failures of normal organ function and are modulated by long-term trends in environmental factors.

The interactions of disease, disability, and host characteristics in the epidemiology of aging are consequently more complex than for chronic diseases – in part because boundaries between declines in physiological function with age and age-related chronic disease processes become more difficult to define as the host's functional age increases. The need for specialized methods, data, and models also increases as, as in many developed countries, many more persons now survive to historically extreme ages. This is due to the fact that as life expectancy increases at later ages (e.g., above age 65 or 85), there is greater potential for the host physiology and the natural history of the disease to systematically change with age – and in ways that may not have been observed in the past. For example, in US Asian and Pacific Islanders, Census Bureau period life expectancy estimates for 1993 were 86.2 years for females and 80.2 years for males. This is higher than in Japan, the country with the highest life expectancy at birth (i.e., 85 years for females and 78 years for males in 2004), or in Okinawa, the Japanese prefecture with the highest life expectancy. In the small European country of Andorra, female life expectancy in 2004 was 86.6 years – 80.6 years for males. These life expectancies exceed what had been assumed to be the biological limit to human life expectancy as recently as 1980.

Not only are the US elderly (65+) and oldest-old (85+) populations growing rapidly, but also the fastest growing populations are even older. Kestenbaum found that the US centenarian population grew 7% per annum between 1980 and 1987, with that growth rate continuing – perhaps even increasing – after 1987. Similar rapid growth rates (i.e., 7–8% per annum) for centenarian populations have been observed for longer periods (i.e., two to three decades) in several European countries. Jenune suggested that no one may have survived to age 100 before 1800 and to age 110 before 1931. Thus, the emergence of large centenarian populations is a recent demographic phenomenon.

In addition, there is evidence of long-term (100+ years) declines in the age-specific prevalence of chronic disability and morbidity at late ages. Fogel and Costa and Costa found that chronic morbidity and disability prevalence declined 6% per decade for the 75 years between which Civil War veterans aged 65+ applied for pensions in 1910 and World War II veterans did so in 1985. Manton and Gu found declines in US chronic morbidity and disability prevalence over age 65 from 1982 to 1999. The rate of decline in disability prevalence was much faster (1.7% per annum) than earlier in the century, with a major acceleration in the decline (to 2.6% per annum) appearing to occur 1994 to 1999.

Thus, not only are there more very elderly persons, but the health of the extreme elderly population is systematically changing, providing evidence of the plasticity of human aging processes in individuals of extreme ages (e.g., to ages 95+) – with researchers now routinely observing disease – age interactions that had been extremely rare. Perls found that persons 95+ may be, on average, healthier than persons 20 years younger due to mortality selection. Fiatarone and colleagues found that physical function could be significantly improved at extreme ages (90+) by weight training supported by improved nutrition.

Until the 1990s, there had not been sufficiently large numbers of extreme-elderly persons in studies to analyze the trajectory of health processes at those ages. They were initially examined in intensive longitudinal studies of small (e.g., $N=273$ in the first Duke Longitudinal Study of Aging; $N=512$ in the Second Duke Longitudinal Study; the Baltimore Longitudinal Study of Aging) select elderly cohorts in local areas. A major task for epidemiological studies of aging is to discern the physiological consequences of age-related disease processes (e.g., chronic diseases such as cancer, whose risk increases as a function of the time exposed) from age-dependent processes (i.e., those related to physiological processes of senescence, e.g., the role of the telomere in affecting the fidelity of genetic trait transmission) at extreme ages in general populations. How these age–disease processes operate in the extreme-elderly population will have major consequences for US health and long-term care policy because of the high average per capita needs of those persons.

Also needed to study health at late ages are specialized longitudinal study designs to distinguish aging effects from age-related disease. For example, in studies of immune function change with age, the 'senieur' protocol was developed to exclude persons with 'latent' or early disease from control groups. Early clinical studies of aging processes found that representative samples of elderly populations give different estimates of the age rate of loss of physiological function than study populations with persons with existing chronic disease selected out to remove explicit chronic disease effects. Put differently, because the prevalence of chronic diseases increases strongly with age, it must be controlled at selection into a longitudinal study population to determine intrinsic rates of aging – as opposed to population rates of physiological change contaminated by chronic disease effects. For example, Kasch *et al.* found that the age rate of decline of cardiac function in physically active elderly populations increased at half the prior rate estimate. Kitzman and Edward, in examining changes in the myocardium with age, found that many changes once attributed to aging were caused by specific pathological processes. Other studies found relations between the shortening of telomeres in bone marrow progenitor repair cells and atherogenesis.

Another factor requiring study in the epidemiology of aging is that, along with the aging of the individual, there is a lengthy temporal trajectory – or natural history – of chronic disease processes. In infectious disease epidemiology, the natural history of a disease was often the life history of a pathogen progressing through stages of development (and degrees of infectivity) in different disease vectors (e.g., the natural history of the malarial plasmodium). This is different from studying either the cause of a chronic disease or changes in its manifestations in hosts of different physiological ages. For example, several studies found a significant prevalence of atherosclerotic plaques in young populations (e.g., in the Pathobiological Determinants of Atherosclerosis in Youth [PDAY] study at ages 15–34). Depending on interactions with risk factors (e.g., high- and low-density lipoprotein [HDL-LDL] ratio, smoking, diabetes, hypertension, factors affecting fibrinolysis, homocysteine metabolism, the production of free radicals and lipid oxidation, and growth factors affecting smooth muscles in arterial intima), atherogenesis proceeds at different rates in different persons at different ages. In interaction with stress and neuroendocrinological factors, ischemic disease of the myocardium may cause infarction, ischemia, and myocyte loss (death of myocardium). Surgical procedures and thrombolytic agents applied early in the ischemic infarction process may minimize loss of myocardium. In 2005, the use of progenitor bone marrow cells was found to modulate atherogenesis in children with genetic defects (Hurler's syndrome), with the prospect that such cell therapy may significantly delay onset of atherosclerosis in the elderly (*see* Atherosclerosis).

In highly industrialized societies such as the United States and Germany, the age-related evolution of the natural history of heart disease may be quite different. The 1988–91 National Health and Nutrition Examination Survey (NHANES III) documented the rapid achievement of many of the goals of the National Cholesterol Education program in the US population – reducing both the population mean cholesterol level and the proportion of the US population with elevated (>240 mg/dl) cholesterol. Gregg *et al.* documented declines in cholesterol, hypertension, and smoking over 40 years of the NHANES, with larger declines for people with high BMIs – only one risk factor (obesity) showed increases but accompanied

decreasing effects on mortality. In Germany, Hoffmeister and colleagues found that in cardiovascular disease (CVD), mortality declined 19% between 1984 and 1989 for persons 25–69 – mainly because of improved medical interventions and reduced case fatality rates, with some risk factors (i.e., total cholesterol and body mass index [BMI]) showing adverse trends. Thus, congestive heart failure (CHF) may be, in the future, more prevalent in those above age 70 in Germany than in the United States. In the United States, despite large decreases in stroke and coronary heart disease (CHD) mortality, CHF mortality and hospitalization rates continued to increase initially. The first declines were documented (in 1989) due to use of angiotensin-converting enzyme II (ACE-II) inhibitors but may also reflect population changes in lipoprotein profiles, the health effects of which may require 5 + years to become fully manifest (*see* Cardiovascular System; Cholesterol and Cell Plasma Membranes).

Concern has been raised that an obesity 'epidemic' is occurring in the United States that could reverse recent improvements in health (e.g., declines in disability from 1982 to 1999). Flegal found that the health effects of increases in BMI were overstated – especially in the elderly population. The net effect of abnormal (both under and over) body weight on US mortality was 25 000 deaths – making it the seventh-ranked mortality risk factor in the United States. The net effect was small, because the 'overweight' category – BMI of 25 to 29.9 – showed 86 000 fewer deaths than expected. Some evidence suggests that part of the long-term shift (increase) in the distribution of BMI may be associated with technophysiological evolution, in which environmental factors enhanced the rate of improvement in health – which was manifest in long-term increases in body size.

Critiques of the war on cancer are also undergoing revisions in that cancer mortality has been declining in the United States since 1990 – with declines (about 11%) continuing to at least 2004. These declines seem to be due both to improved treatment of diagnosed cancer (e.g., increased long-term breast cancer survival) and, as documented in NCI's SEER program, to reductions in cancer incidence (in part due to reduced smoking). It seems also that new cancer treatment technologies targeted to specific solid tumors (e.g., Herceptin to specific types of breast and pancreatic cancers) in adults have begun to show significant benefits.

The 'natural' history of certain cancers under treatment has also changed, in that, with improved surveillance to detect microdisease recurrence, it may be possible to intervene before recurrence becomes systemic. If a recurrence is detected early enough, therapies effective in treating early-stage disease may also prolong survival in early recurrent disease (*see* Cancer and Age). This may turn cancer into a chronic condition that is increasingly prevalent in the elderly rather than a major cause of acute deaths, as has been partly achieved in the United States for HIV.

Some cancers, such as prostate and multiple myeloma, have a strong age dependence, increasing in prevalence as the population ages. A predisposing condition for multiple myeloma, monoclonal gammopathies of unknown significance (MGUS), has prevalences as high as 19% in occidental populations aged 95 + . Thus, the process triggering these cancers may have a more direct relation to the genetic basis of the senescence of certain organ systems in specific racial groups (e.g., prostate cancer risk). Prostate cancer risk also rises rapidly with age and is less prevalent in Asian than in either White or Black populations.

A third factor in the epidemiology of aging is that instead of studying specific diseases, one may study age changes in the degree and type of disability of the host. This is significant in the epidemiology of aging because of the longer natural history of chronic disease processes, the greater likelihood of multiple diseases coexisting (and interacting), and the fact that a disease at the same stage may have different effects on the functioning of hosts of different physiological ages. Loss of function also may trigger lethal chronic disease. Colantonio and colleagues found loss of function to be a risk factor for stroke. Osteoporosis can lead to hip and vertebral fractures that cause disability and predisposition to diseases related to physical debilitation (e.g., pneumonia, peripheral circulatory disease, heart disease) (*see* Osteoporosis and Aging Related Bone Disorders).

Measuring functional loss is difficult in elderly populations because one is not assessing the presence or absence of a disease, but the impact over time of one or more of many predisposing diseases on the host's ability to perform specific life-sustaining functions (e.g., activities of daily living [ADLs] or instrumental ADLs [IADLs]). One also needs to assess functional changes over age (e.g., 'active' life expectancy) as well as discriminate quantitatively between different types and intensities of disability. Manton and colleagues showed how multivariate procedures could be used to identify the dimensions of function from batteries of functional and physical performance measures. There are conceptual issues involved in disability measurement that affect data collection. There is no overall 'gold standard' to validate the diagnosis of disability. Different researchers may make observations about disability that may have equal validity for each study's goals. For example,

self-reports of disability may better reflect the morale of the elderly individual and his or her self-perception of what his or her functional capacity 'should be.' This may predict the behavior of an impaired older person better than physical performance evaluations. That behavior may translate into further health and functional changes – especially in the very elderly (e.g., persons remaining active at later ages better maintain function and health).

A fourth area in the epidemiology of aging is the need to assess multiple interacting disease and disabilities. With age, the likelihood of manifesting a second (or third or fourth) disease increases. This is complicated, because in order to survive to such late ages as to incur comorbidities, the initial disease process must not be rapidly lethal. Thus, the presence of multiple comorbidities can be an indication of survival to late ages and possibly the prevalence of less aggressive forms of specific diseases (e.g., as in prostate cancer). This suggests that the threshold for defining disease, or a risk state, changes with age (e.g., changes in the criteria for hypercholesterolemia or systolic hypertension with age). This is an area of potential controversy because, although longitudinal studies may suggest decline with age in the risk associated with a particular risk factor level (e.g., a total cholesterol of 240 mg/dl), that decline may be the result of increased prevalence of chronic diseases with age. Alternately, persons in good health at late ages may have the same risk for a given risk factor level as a much younger person. This affects decisions about whether treatment of diseases should change with age. The Systolic Hypertension in the Elderly Program (SHEP) trials found that significant reductions in stroke were achieved by treating isolated systolic hypertension at late ages. In contrast, mildly elevated diastolic blood pressure (DBP) at late ages may indicate the ability of the heart to maintain perfusion even with some loss of arterial compliance – low DBP may imply impaired cardiac response (e.g., partial 'pump' failure).

A fifth concern in the epidemiology of aging is that effects of genetic factors may be different at later ages due to mortality selection. In twin studies, the maximum risk associated with a genetic predisposition to circulatory disease occurs in middle age. The risk of genetic factors tends to decline at later ages. This is likely due to lethal genetic manifestations of chronic diseases selecting out susceptible persons so survivors to late ages have more complex and subtle genetic predispositions to disease. Marenberg and colleagues showed this in a large Swedish study of CHD mortality risk in monozygotic (MZ) and dizygotic (DZ) twins. The relative risk of CHD death in MZ twins was about 15:1 in middle age – but was 1.0 at ages 85+. Similar age patterns of genetic effects were noted in other twin studies. Selection appeared to reduce the prevalence of the ApoE4 genotypes in Finnish centenarians, as well as thyroid autoantibodies in Italian centenarians and human leukocyte antigen (HLA) markers for adult-onset diabetes in Okinawan nonagenarians and centenarians. Similar effects of mortality selection on genetic risks are noted for specific cancers. Lung cancer associated with a genetic predisposition due to dysfunctions in the cytochrome P450 enzyme system had a prevalence of 69% at age 50 but 22% at age 70 (*see* Behavioral Genetics).

Conceptual Frameworks

These differences suggest that the epidemiology of aging requires specialized data, concepts, and methods to deal with the complex dynamics of multiple interacting disease and aging processes. This is illustrated in **Figure 1** by a model based on a generalization of the life table survival function (1_x) where there are 'survival' functions for morbidity and disability as well as mortality.

In **Figure 1** there are three survival curves for a hypothetical cohort. The outermost curve (C) reflects the proportion surviving to age x. The second (B) reflects the proportion of the cohort surviving to age x free of disability. The third (A) reflects the proportion surviving to age x without chronic morbidity. Areas between curves represent the number of person-years expected to be lived in a health state. For example, the area under curve C reflects the total number of person-years lived. Life expectancy is calculated by dividing the number of person-years lived by the initial cohort size. The area under curve B is the number of person-years lived without disability (but possibly with nondisabling diseases). Dividing this number of person-years by the initial cohort size yields 'active' life expectancy. The area under curve A represents the number of person-years lived free of morbidity. Division of this by the initial cohort size yields 'healthy' life expectancy.

Figure 1 is an idealization of health processes in a birth cohort because there can be many specific chronic diseases examined and because disability may vary considerably in type (e.g., cognitive impairment, lower limb impairment leading to problems with mobility) and intensity. The survival curves in **Figure 1** can be calculated in different ways depending on the data available. The most basic computations use life tables estimated from vital statistics data and disease and disability prevalence estimates from cross-sectional health surveys. Such procedures are limited in that health transitions and improvements

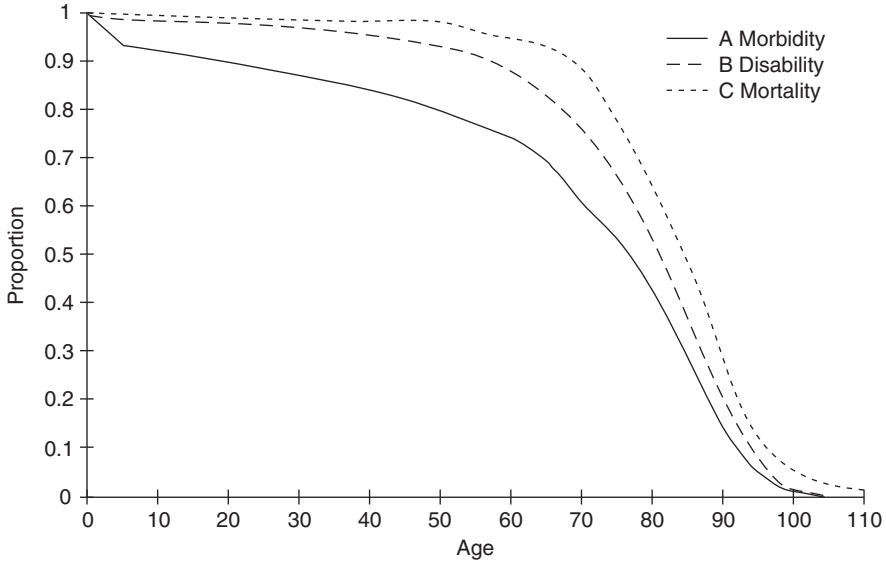

Figure 1 Theoretical relations of morbidity, disability, and mortality outcomes, represented by the change in survival over age.

in individual functioning are unobserved in cross-sectional data. To estimate models with bidirectional changes in health and function, longitudinal data are needed – with consideration of how the temporal structure of the observational plan detects health episodes of different durations. Nonetheless, **Figure 1** is useful to emphasize the changing linkage with age of mortality and disease dynamics. Even implementation with prevalence data gives useful summaries of the population impact of disease and disability at a point in time.

Fundamental to evaluating models like **Figure 1** are the effects of biological life span limits on the age linkages of mortality, disease, and disability. In many areas of epidemiology, life span limits are not important because ages that are truly extreme for humans as a species are not often studied. Studies of nonagenarians and centenarians are often restricted to small populations. The effects of life span limits are related to the rectangularization, or 'squaring,' of the human survival curve and to the 'compression of mortality.' This raises questions about the effects of life span limits on the age-specific linkage of mortality with other health events. Such questions have been termed the 'compression of morbidity' (i.e., whether the age at onset of disease or disability can be changed or delayed without increasing life expectancy). Some study designs may address this problem (e.g., in the National Long Term Care Survey of 1994, 1999, and 2004, oversamples of 540, 600, and 1584 persons age 95+ were conducted to improve precision of parameter estimates at extremely late ages). Another approach is to combine several similarly structured studies in a single analysis.

The concepts of morbidity and mortality compression raise the following additional questions:

1. Is there an upper limit to the age to which persons may survive?
2. What is the shape of the survival curve as the life span limit is approached (e.g., how does the variability in the distribution of ages at death change)?
3. How is the age relation of morbidity and survival curves affected as the life span limit is approached?

The maximum life span is difficult to identify (if a specific value exists) because one can only know the lower bound to the life span limit (e.g., a French woman died at a documented age of 122). Of greater interest is how individual life span potentials are distributed in a population. Manton and Tolley also raised questions about the formalization of concepts of survival curve rectangularization, suggesting that difficulties in formalization may prevent a rigorous statistical evaluation.

Questions about the compression of mortality involve the way in which the genetic heterogeneity in the maximum life span for individuals is distributed. This is important because it determines the irreducible variability in the distribution of those limits. If there is considerable irreducible (e.g., genetic) heterogeneity, then the survival curve may never rectangularize as in **Figure 2**.

Figure 2 shows the three survival curves from **Figure 1** and a 'rectangularized' survival curve, C^*. Though life expectancy is roughly the same for C and

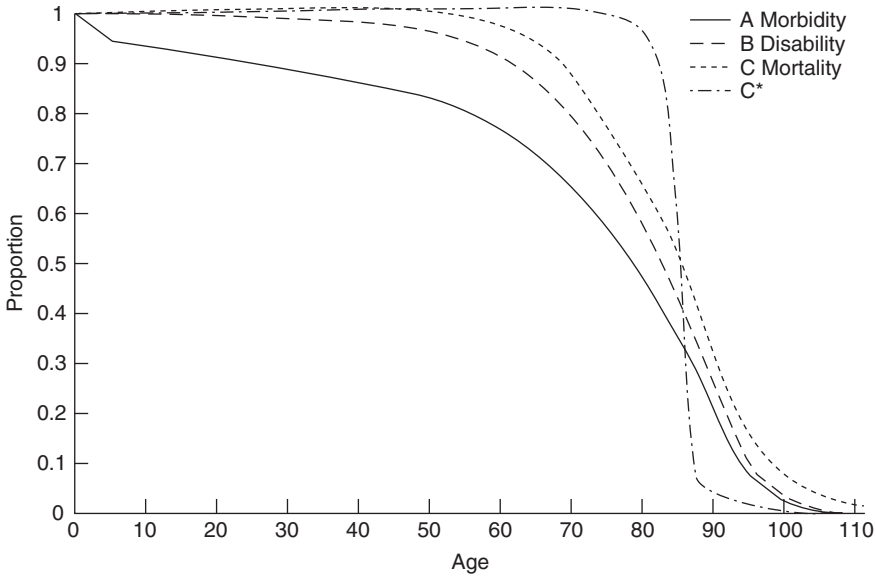

Figure 2 Theoretical relations of morbidity, disability, and mortality outcomes, represented by changes in their survival curve with the survival curve for mortality drawn to represent (A) a highly rectangularized mortality age pattern (C*) and (B) an age pattern of mortality with significant intrinsic heterogeneity.

C^* (i.e., the median life span is 90 years for both), survival curve C has more variability (i.e., the standard deviation for C is about 5 years; for C^* it is less than 1 year).

Empirically, as US life expectancy has increased, so has the variability of age at death; hence both life expectancy and the highest observed age at death increased. In one set of official Social Security life tables for 2000, female life expectancy was 78.7 years and was projected to increase modestly, by 2080, to 84.6 years ($+5.9$ years). For males, the increase was 6.6 years (i.e., from 71.6 to 78.2). The increase in life endurancy (i.e., the age to which 1 in 100 000 persons can expect to survive) is over 12 years for both males and females over the same period. Thus, the upper limit of the age-at-death distribution is expected to increase twice as fast (i.e., to 125 or more years) as life expectancy. This is different from what occurred from 1900 to 2000, when life expectancy increased 39.2 years for females and 25.2 years for males, whereas life endurancy increased only 7 to 8 years. This is because most life expectancy increases from 1900 to 2000 were due to mortality declines at early ages. After 2000, there was less potential for change at those ages. This again implies that the epidemiology of aging has to deal with phenomena that are historically unprecedented; hence, there will necessarily be a greater reliance on biological theory and ancillary data. Of course, a critical issue is how curves B and A will change over age as C changes. Perl suggested that the distance between the disability (B) and mortality (C) curves will be at its maximum at ages 75–85 and will decline above age 95.

There may be no simple model for the limited distribution of ages at death in that, at advanced ages, many genetic effects will interact in complex ways with the environment. Because humans have long life spans and live in heterogeneous environments, it is difficult to isolate genetic and environmental influences on disease risks to assess how health changes at late ages (i.e., age changes in the relation of the three curves above age 95). This is why new observational plans and data are needed.

The shape of the US survival, morbidity, and disability curves has practical implications for health interventions – both preventative and therapeutic. If interventions to change the relations of the curves are to have significant benefits, they must be introduced sufficiently far from the life span-limiting distribution and the associated morbidity and disability curves to produce a sizable effect over time.

Study Designs

Resolution of many of the issues raised previously requires special longitudinal observational plans. A problem in designing such plans is that many questions about aging and disease processes may be so detailed that experimental and clinical studies are needed to answer specific design issues before population studies of very elderly populations are fielded. For example, the role of antioxidants in preventing disease has been investigated in a number

of studies. Vitamin E may reduce circulatory disease by slowing atherogenesis and improving glucose metabolism, although the consumption necessary to cause such effects may be higher than the standard recommended daily allowance (RDA) (e.g., 100 vs. 30 international units). Certain chemical forms (isomers) of specific micronutrients may have different physiological effects. Prasad-Edward found that alpha tocopheral succinate (as opposed to alpha tocopheral acetate) may be a more powerful cellular redifferentiating agent than vitamin A. Other isomers of vitamin E were not as biologically active. Similar issues have been raised for vitamin D isomers in treating osteoporosis. Combined use of N-acetyl carnitine and R alpha lipoic acid have been suggested to alter mitochondrial functions and thus to improve age-specific levels of function in animal models.

It is unlikely that trials and population studies can evaluate all possible isomers and uses of micronutrients for altering age-related biological activity. The selection of the forms of micronutrients evaluated in population studies and the levels of supplementation examined will have to be informed by the consensus of experimental and laboratory results (*see* Diet and Nutrition).

Major issues in study design are differential rates of selection with age in populations and the temporal structure of the observational plan and its ability to identify disease and disability episodes of different durations. A major area for innovation in study designs of elderly populations is emerging because the quality of US population and mortality data is improving. This is due, in part, to the introduction of Social Security in 1935 and Medicare in 1965, which increased birth registration in the US population, and, at the ages of entitlement, the requirement to provide rigorous proof of age to receive benefits. Furthermore, the education of elderly cohorts (e.g., ages 85 to 89) has improved since 1980 and will continue to improve until at least 2015 – a time when those oldest-old cohorts will have high proportions of better educated persons. Because of these changes, age reporting in Social Security and Medicare mortality records is of excellent quality (up to at least age 100 for Whites) and will further improve as time passes.

This implies that a *de facto* computerized population registry is gradually developing in the United States, one whose quality of age reporting at late ages (e.g., 95+) increases with time since the innovation of its major components. Thus, there are computerized data systems containing lists of all Medicare-eligible persons from which samples of elderly persons can be drawn for health surveys and studies for specific points in time. This has advantages over the area-probability survey designs based on census data that are employed in many national health surveys. In list samples, specific elderly individuals are sampled. Because the Medicare list contains data on the age of the person, oversampling of persons at extreme ages can be done from the nearly complete listing of the US elderly population. A person-based sample means that residents in facilities of all types are included. Follow-up for reinterviewing can be done through Medicare files so that nearly 100% of persons from a prior sample can be tracked and the characteristics of non-respondents identified. In Medicare files, reported ages and dates of death are available – as well as information on Medicare-reimbursed use of health services. Analyses suggest ICD-9 (International Classification of Diseases, Ninth Revision) diagnoses in Medicare files reliably report on disease incidence functions.

In area probability samples, households in an area are sampled; hence characteristics of individual elderly non-respondents are not directly available. The lack of an administrative list sample also means follow-up of individuals – and identification of decedents – is more difficult and likely less complete. Because censuses are done only every 10 years, sampling must be based on estimated population characteristics at points in time potentially distant (e.g., 9 years) from when the census data are drawn.

Thus, the availability of Medicare-based list samples allows one to draw national samples and to better track them. Mortality selection and population representativeness can be assessed more completely and on a near real-time basis. This allows for national longitudinal sample survey designs like that of the National Long-Term Care Survey (NLTCS) (**Figure 3**). The NLTCS has been conducted in 1982, 1984, 1989, 1994, 1999 and, most recently, 2004. Survey records are linked to Medicare service use and mortality files for the entire period. Since the NLTCS is a true longitudinal survey, bidirectional individual health transitions are observed. Because individuals are sampled, persons living in both the community and in institutions of all types are sampled. This was a difficulty in the 1984 Supplement on Aging (SOA) and the 1986, 1988, and 1990 LSOA follow-up (i.e., the 1984 SOA sample was only of community residents so that an institutional sample had to be accumulated over time – as in the current Health and Retirement Survey).

There are three types of supplementary sample in the NLTCS. The first, because the US prevalence of chronic disability was unknown in 1982, required drawing a sample of 35 000 individuals (of a total of 55 000 initially drawn from Medicare lists) to get 6000+ detailed community interviews in 1982. There

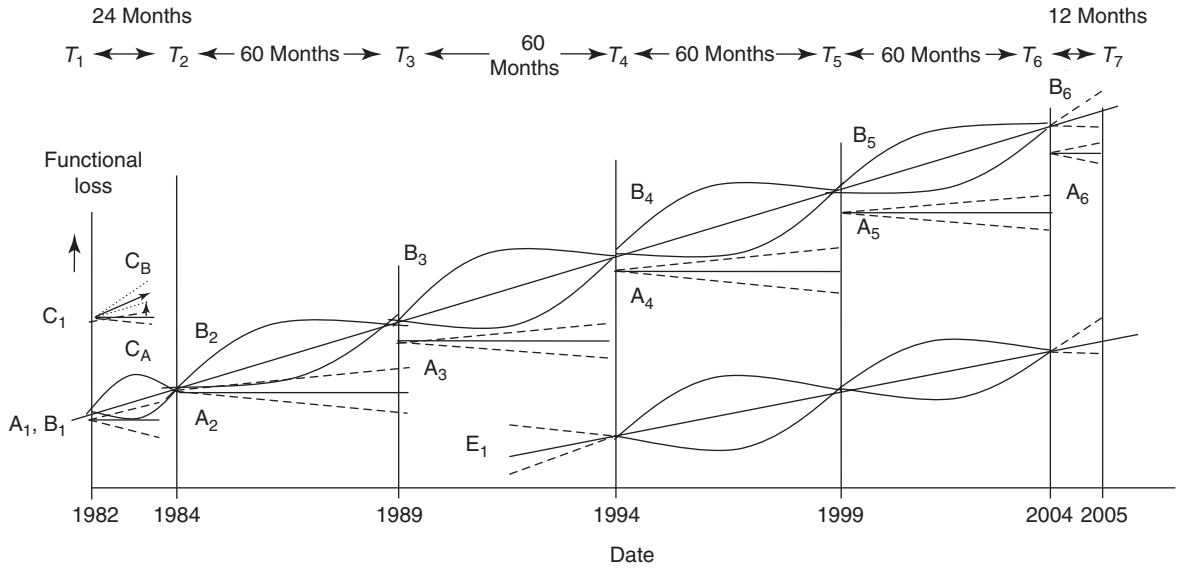

Figure 3 Temporal organization of the 1982, 1984, 1989, 1994, 1999, and 2004 NLTCS Longitudinal Observational Plan and illustrative trajectories of functional loss with time, and changes in the range of uncertainty about the level of functional loss relative to the time position between assessments.

were 26 623 persons who in 1982 were screened and reported no chronic disability. This sample was larger than needed to meet statistical power requirements for estimating disability incidence rates between 1982 and 1984. Consequently, in 1984 only 12 100 persons in the non-disabled sample component were rescreened. The remaining cases define a reservoir of persons, all 65+ in 1982, who could be drawn from for screening at future dates (i.e., 1989, 1994) to maintain the sample size of very elderly (e.g., 85+) persons who have high mortality. Second, to ensure that each cross-sectional sample was representative of all persons 65+, new samples of about 5000 persons passing age 65 between surveys were drawn from Medicare files and screened for disability. Thus, all NLTCS waves represent the total US 65+ population at each survey date. Third, starting in 1994 two additional sample supplements were drawn – persons age 95+ and healthy persons screening out.

With 22 years of follow-up (1982–2004), it becomes possible to make comparisons of the health of very elderly cohorts. Five-year intervals are long enough for significant changes in health and functioning to emerge in the population. Though a 5-year interval misses health transitions occurring in inter-survey intervals, persons in episodes of all lengths are captured in each sample. The shorter transitions occurring between surveys are also represented in linked Medicare service use, diagnosis, and vital statistics files.

Because the likelihood of sampling a health episode is related to its length, the proportion of short episodes sampled will be small. The weighting of individuals to produce national estimates of health transitions is complex, because the interview period is approximately 4 months and attrition of sample members within an interview period has to be considered. Because the exact dates of death within an interview period can be linked to survey responses in a prior NLTCS interview, left censoring bias can be reduced.

It is possible to systematically supplement the samples and make weight calculations because the US population proportions at any point in time are known from Medicare lists and service records. For census-based samples, the population proportions are 'known' only every 10 years; between censuses only estimates are available. Thus, in the 1994 NLTCS, a supplementary sample of 540 persons age 95+ could be drawn to improve the precision of health change estimates at late ages. In 1999, the 95+ oversample was 600 persons, while in 2004 this was increased to 1584.

The content of core disability and health conditions in the NLTCS was held constant over time in order to monitor health changes over time. Within the time limits for respondent burden in a face-to-face interview of elderly persons, it was possible in the NLTCS to ask supplementary batteries of questions. Because all disabled persons are interviewed in person, proxy response rules are easier to implement. An in-person interview is also a better modality for establishing the status of a very disabled person than a telephone interview (e.g., for sensory-impaired persons).

In the 1999 NLTCS, funding was received for a pilot biomarker study that was actually fielded in 2001.

In **Figure 3**, there is a joint distribution of continuous monitoring of vital status (and Medicare service use) between surveys and detailed assessments at survey times. Can information from this joint distribution be used to improve estimates of mortality risks and health transitions over time? Some estimates can be made directly (e.g., 5-year rates of disability improvements and decrements for specific ages and by gender). With appropriate analytic models calibrated during the NLTCS interim period and with responses linked to Medicare records, it is possible to extract more information from the observational plan about complex underlying health processes using disability functions calibrated from Medicare service use and diagnostic data that is available for any time between interviews.

For example, detailed assessments of physical function were made in each NLTCS interview. With detailed batteries of functional items, multivariate procedures could be used to (1) identify K reliable dimensions of functioning from J items and (2) calculate scores, calibrated as a function of age and data, representing the degree to which a person is characterized by each dimension. With sets of scores calculated for individuals, it is possible to examine two different models, both illustrated in **Figure 3**, to evaluate continuous changes in health. First, the disability scores could be assumed to be constant for an individual over an interval (i.e., changes occur instantaneously at the time of the next survey). This implies that uncertainty about a person's status increases until the next assessment – then it drops to zero. This is represented by the lines connecting A_1 to A_2, etc. Alternately, a model can be assumed to describe changes in an individual's disability scores between two surveys as a function of Medicare records. In **Figure 3**, between NLTCS observations B_2 and B_3, scores are assumed to change linearly. This implies – because information at the beginning and end of the observation period is used – that uncertainty about the state of the person in the intersurvey period is at a maximum in the middle of the interval and then decreases to zero when new measurements are made. Medicare data may reduce uncertainty (narrow the 'uncertainty' envelope) at any point in the interval.

Analytic issues remain for 'left-' and 'right'-censored cases. Left-censored cases are represented by the 'age-in' samples (i.e., persons passing age 65 before an interview) (e.g., E_1). Left censoring is less of a problem in a longitudinal survey because prior states of persons are often known – an important rationale for continuing longitudinal studies and surveys. Right-censored cases are represented either by persons dying between surveys (person C_B) – or by the status of persons after the last interview (e.g., B_5). Both problems can be resolved by assuming that persons whose observations at a future (or past) survey were censored had the same rate of change on the K scores as did persons observed at both times – after cases are matched on disability scores (and other demographic – e.g., age, sex – and social variables) at the time when both cases were observed. In this way, a monthly disability trajectory can be imputed up to the time of death for person C_B. Imputed values for the disability scores at the month prior to death can be used to estimate disability-specific mortality functions. Because persons who die (i.e., are right censored) are not observed at two time points, uncertainty about imputed disability scores increases to the time of death, or other censoring (e.g., end of follow-up; B_6).

This approach uses the 5-year interview data to make inferences about more short-term health transitions by estimating monthly rates of change for the continuous disability scores. If, in contrast, the survey information is used only to classify persons as disabled or not disabled, then there is no information on the rate of health changes between surveys to determine when an event occurred in the interval. The use of continuous change in scores, assuming that the model of change is reasonable, avoids that problem. Use of the linked Medicare service use files in a dynamic model further informs estimates of between-survey disability changes. For example, for a 95-year-old person starting in good health (e.g., no ICD-9 diagnosis in the Medicare records), there is a greater likelihood of a change in disability than for a 65-year-old person in good health. However, health and functional change may be more rapid for a 70-year-old with an ICD-9 diagnosis of diabetes than for a healthy 95-year-old – with rates also possibly different for males and females and for different types of disability.

The combined use of models and mixed data observational plans may be the only practical way of studying longitudinal health changes in elderly community and other study populations. This is because in a given local community, the number of extreme-elderly ($95+$) may be limited and the rates of changes at late ages (e.g., >90) so rapid that any interview (or assessment) period short enough to adequately capture those rapid changes in a small population will lack the necessary statistical power.

Using a model of continuous time changes in health and function also facilitates use of ancillary data from select community and clinical populations. That is, the assumed mathematical structure of underlying health changes allows data across populations – and over age and time – to be systematically combined

with that joint distribution, providing more statistical power to resolve questions than from using the studies individually.

Summary

The special data and analytic problems intrinsic to the development of an epidemiology of aging were reviewed (i.e., an epidemiology considering interactions of aging and disease processes up to the biological limits of human survival). These specialized data collection and analytic procedures are needed when exploring health changes at the extreme ages observed in human populations. In middle-aged populations, the same analytic problems exist, but with smaller effects – e.g., at age 50 the effects of selection on disease–risk factor relations on estimates of the hereditability of disease traits exist, but will be small for populations with life expectancies over 70 years.

The applicability of such methods also depends on gender, because in females age changes in hormonal status are abrupt because of menopause. For example, the risk of osteoporosis increases rapidly for postmenopausal females. Less well understood are the complex patterns of risk factor–disease interactions that menopause may stimulate in females. Moon and colleagues posited a strong interaction of osteoporotic changes and atherogenesis in postmenopausal females. In addition, changes in female body iron stores may interact with osteoporosis and atherogenesis to affect disease risks. Thus, the need for specialized analytic procedures may occur at younger ages in females due to rapid hormonal (and associated physiological) changes at menopause (*see* Endocrine Function and Dysfunction).

In contrast, selection effects in males may become relatively more rapidly manifest than in females because of females' longer life expectancy. For example, although the incidence of chronic disability may be similar at ages 60 to 80 for males and females, the female prevalence of disability tends to be higher because women survive longer at each disability level at each age. Determining whether special procedures are required for a specific analysis requires a case-by-case evaluation, because the underlying processes they are meant to deal with can initiate at relatively early ages. Thus, there is a continuum of needs for age-specialized epidemiological data collection and analytic methods.

See also: Atherosclerosis; Behavioral Genetics; Cancer and Age; Cardiovascular System; Cholesterol and Cell Plasma Membranes; Osteoporosis and Aging Related Bone Disorders.

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Erectile Dysfunction

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Glossary

Erectile Dysfunction (ED) – The persistent or repeated inability, for a duration of at least 6 months, to attain or maintain an erection sufficient for satisfactory sexual performance.

Epidemiology and Definitions

Erectile dysfunction (ED) is defined as the persistent or repeated inability, for a duration of at least 6 months, to attain or maintain an erection sufficient for satisfactory sexual performance. This National Institutes of Health (NIH) definition deemphasizes intercourse as the only objective parameter of sexual function and allows for a broader interpretation of ED.

It is estimated that between 18 and 30 million men in the United States are affected. Aging and concomitant other medical problems such as atherosclerotic vascular disease, hypertension, diabetes mellitus, hypercholesterolemia, heart disease, and cigarette smoking are associated with a higher prevalence of ED. Specifically, the Massachusetts Male Aging Study (MMAS), a population-based questionnaire survey of 1290 men between the ages of 40 and 70, revealed the presence of ED in 52% of the volunteers.

The National Health Social and Life Survey (NHSLS) is a more recent epidemiological population survey of 1410 men aged 18 to 59 that reported a 31% prevalence of male sexual dysfunction. Premature ejaculation (21%), hypogonadism (5%), and ED (5%) were the three most common male sexual dysfunctions noted in this important study.

In order to compare the independent effects of aging on ED to the effects of comorbidities typically associated with aging, a group of investigators performed an evaluation of ED in men 65 to 75 years of age in comparison to men older than 75 years of age.

The findings indicated that age alone increased the relative risk of sexual dysfunction (relative risk of 2.2 for men 65 to 75 years old and 7.9 for those older than 75). In addition, self-reported poor health, diabetes, and bowel or urinary incontinence increased the risk of sexual dysfunction in all age groups. The authors thus demonstrated that aging, as well as the comorbidities that are often associated with aging, may independently or synergistically contribute to ED.

Anatomy

The penis is composed of the paired corpora cavernosa (erectile bodies) and the corpus spongiosum, the tissue that surrounds the urethra. Ejaculation is facilitated by the rhythmic contractions of the bulbospongiosus muscles surrounding the corpus spongiosum in the bulbar region of the penis. The tunica albuginea is the fibrous tissue surrounding the outer covering of the corpus cavernosum. Pathologic fibrous tissue plaque formation in the subtunical layer (Peyronie's disease) results in decreased elasticity of the tunica albuginea, penile curvature, and veno-occlusive ED. Lacunar spaces are specialized, widely communicating endothelial-lined vascular spaces in the interior of the corpus cavernosum that are surrounded by the trabeculae consisting of connective tissue and corporal smooth muscle.

Blood vessels and nerves run between the tunica albuginea and the Buck's fascia, a thick, elastic layer that surrounds the tunica albuginea. Penile blood supply comes from the internal pudendal artery and its three terminal branches: the bulbo-urethral, cavernosal, and dorsal penile arteries. The accessory pudendal artery is a source of additional blood supply to the corpora cavernosa and may have a critical role in men who have undergone radical pelvic surgery with compromised pudendal arterial blood supply. Within the corpora, the cavernosal artery branches into the helicine arterioles, resistance vessels that open into the lacunar spaces.

Venous blood from the corporal sinusoids drains initially into a series of subtunical venules that coalesce into emissary veins. The latter pierce through the tunica albuginea and empty into the deep dorsal vein, directly or via the circumflex veins. Extratunical venous drainage occurs via the deep dorsal, cavernous/crural, and superficial dorsal veins. Through the emissary and circumflex veins, most of the venous flow from the distal corpora drains into the deep dorsal veins that empty into Santorini's vesicoprostatic plexus. The cavernosal and crural veins drain the proximal corporal bodies and lead to Santorini's vesicoprostatic plexus and the internal pudendal vein. The superficial dorsal vein drains blood from the pendulous penile skin and glans and communicates with the deep dorsal vein. In each corpus cavernosum, bundles of smooth muscle cells embedded in a matrix of connective tissue and fibroblasts form a series of endothelium-lined blood-filled lacunar spaces. In the flaccid state, the trabecular smooth muscle and the central cavernosal and branching helicine arteries within each cavernosal body are constricted and lacunar venous blood passes unimpeded from the subtunical to the emissary to the extratunical veins.

Somatic innervation of the penis occurs via the pudendal nerve, which is composed of efferent fibers that innervate the striated musculature of the perineum and afferent fibers from the penile and perineal skin. In the erect state, increased blood flow to the penis is facilitated by sacral parasympathetic stimulation and subsequent dilation of the cavernosal and helicine arteries. Concomitant relaxation of the trabecular smooth muscle greatly increases the compliance of the cavernosal bodies and allows the lacunar spaces to expand and accommodate the enhanced blood flow. The subtunical venules become stretched and compressed, thus forming the primary site of venous outflow resistance (the veno-occlusive mechanism) during penile erection. The cavernous and crural veins (the deep system) are the main drainage system of the corpora cavernosa and a main source of leakage or failure-to-maintain venogenic ED.

Erectile Physiology

Penile erection is a neurovascular event that is governed by the delicate balance between the contractile and relaxation properties of the corporal smooth muscle. Normal erectile tissue is composed of trabecular smooth muscle (approximately 50%) and extracellular matrix providing a fibroelastic framework. The corporal smooth muscle is contracted in the flaccid state and relaxed in the erect state. Following sexual stimulation, initially contracted helicine arteriolar smooth muscle undergoes relaxation. Receptor-mediated smooth muscle relaxation is initiated by the generation of cyclic nucleotides (cGMP and cAMP) by guanylate and adenylate cyclases, activation of protein kinase G, and a series of molecular events that lead to the eventual inhibition of the sarcoplasmic reticulum Ca^{2+} ATPase (SERCA) pump and intracellular Ca^{2+} sequestration within the sarcoplasmic reticulum.

Relaxation of arterial and trabecular smooth muscle results in dilation of the cavernosal and helicine arteries, increased arterial blood inflow across the endothelial cells lining the lacunar spaces, and penile

engorgement. Penile rigidity is achieved through the increased resistance to the outflow of blood as the trabecular walls expand against the tunica albuginea and the plexus of subtunical venules is compressed (i.e., the veno-occlusive mechanism).

Conversely, the contractile response of the smooth muscle cell is ultimately determined by the interaction between myosin cross-bridges and actin filaments, a process that is mainly governed by the level of intracellular free Ca^{2+}. Release of Ca^{2+} from internal stores is facilitated by the binding of vasoconstrictor agonists to specific plasma membrane receptors and subsequent activation of various intracellular signal transduction pathways. Extracellular Ca^{2+} may also enter the cell through voltage-gated Ca^{2+}channels. Free Ca^{2+} binds calmodulin and promotes its association with myosin light chain kinase (MLCK). Calmodulin-activated MLCK phosphorylates the regulatory light chain of myosin (MLC) to initiate cross-bridge cycling and contraction.

Central Mechanism of Erection

Erection may occur as a result of local sensory stimulation of the genital organs and/or by central psychogenic stimuli. Most of the critical cerebral regulatory functions for erection occur in the hypothalamus and the limbic system. Sexual drive and psychogenic initiation of erection occur in the medial preoptic area of the brain. The medial preoptic area and the paraventricular nucleus within the hypothalamus are involved in the integration of the visual (occipital area), tactile (thalamus), olfactory (rhinencephalon), and imaginative (limbic system) input; they send neural projections to the thoracolumbar sympathetic and sacral parasympathetic centers of the spinal cord.

The locus caeruleus and nucleus paragigantocellularis (nPGi) in the brain stem exert an inhibitory effect on sexual arousal, whereas both dopamine and oxytocin are thought to play important roles in mediating the pre-erectile response in the medial preoptic area and the paraventricular nucleus, respectively. Inhibition of serotonin release from the nPGi nerves projecting to sacral segments of the spinal cord may be involved in depression of sexual function by serotonin reuptake inhibitors (SSRIs). Somatic sensation from genital skin is collected by the pudendal nerve, the afferent limb for reflexogenic erections. The autonomic nerve fibers that arise from the sacral parasympathetic center (S2–S4) make up the efferent limb for this reflex, innervating the penile smooth muscle. Control of penile erection is likely to be regulated by synergistic function of both the reflexogenic and the psychogenic erectile mechanisms.

Following sexual stimulation, the first event in the corpora cavernosa is neuronal-mediated arterial filling. This enables neuronal and endothelial-mediated trabecular smooth muscle relaxation. The subsequent volume change stretches the subtunical venules, creating venous outflow resistance and increased intracavernosal pressure. Elevation in intracavernosal pressure with continued filling further compresses the subtunical venules. Additional arterial filling results in axial penile rigidity, defined as the ability of the erect penis to resist deforming or buckling from vaginal-mediated axial loads. Factors that determine axial penile rigidity include intracavernosal pressure, penile tissue mechanical properties, and penile geometry. Detumescence is brought about by neuronal-mediated smooth muscle contraction with restoration of corporal venous drainage.

Peripheral and Neurogenic Mechanisms of Erection

Erectile function in the penis is regulated by autonomic (parasympathetic and sympathetic) and somatic (sensory and motor) pathways. Innervation of the penis occurs through three sets of peripheral nerves: the sympathetic, parasympathetic, and the pudendal nerves. The main role of the sympathetic system in the regulation of the erectile process is in the initiation and maintenance of arterial and trabecular smooth muscle contraction (the flaccid state). The sympathetic nerves (T10–L2) responsible for detumescence and maintenance of flaccidity project to the corpora, the prostate, and bladder neck via the hypogastric nerves.

The major excitatory input to the penis is provided by the parasympathetic nerves originating from the S2–S4 spinal cord segments. These nerves exit through the sacral foramina and pass forward lateral to the rectum as the pelvic nerve (the efferent pathway) and are joined by the preganglionic parasympathetic nerves originating from S2–S4. The pelvic nerves synapse with postganglionic nonadrenergic, non-cholinergic (NANC) nerve fibers in the pelvic plexus and give rise to the cavernous nerve of the penis that innervates the corpora cavernosa.

Stimulation of the pelvic nerves causes a marked increase in flow through the pudendal arteries and entrance of blood into the cavernosal spaces. Penile stimulation in a healthy man will cause reflexogenic erections that are primarily controlled by the sacral parasympathetic nerves originating in the spinal cord segments S2–S4. The afferent limb of the erection response is mediated by the dorsal penile nerve

(a branch of the pudendal nerve), which transmits sensory impulses to the spinal cord.

Nitric oxide (NO) is the primary mediator of NANC parasympathetic input. NO directly activates guanylate cyclase and is apparently synthesized on demand with little or no storage requirements.

It has been demonstrated that, in addition to guanylate cyclase, NO has other intracellular targets with which it can interact directly and may modulate the contractility of smooth muscle cells independently of the cGMP pathway. The levels of cGMP are regulated by phosphodiesterases (PDEs), a superfamily of hydrolytic enzymes that act on cyclic nucleotides and terminate signal transduction. Several PDE subfamilies with different cyclic adenosine monophosphate or cGMP specificities and tissue localizations have been identified in mammalian tissues. PDEs hydrolyze both cGMP and cyclic adenosine monophosphate; they play a key role in the physiology of erection.

Current FDA-approved oral medications for treatment of ED are inhibitors of the type 5 phosphodiesterase (PDE5).

Pathophysiology of Erectile Dysfunction

Vasculogenic Impotence

Atherosclerosis is a common cause of organic impotence. General vascular risk factors such as smoking, hypertension, cigarette smoking, diabetes mellitus, and hypercholesterolemia may cause arterial ED. Direct blows to the perineum related to falls, sporting accidents, or bicycle injuries, as well as blunt trauma from pelvic fractures related to motor vehicle accidents, may cause arterial occlusive disease to the common penile or cavernosal artery. The typical clinical presentation is that of a patient who complains that erections take longer to develop (diminished spontaneity) and are less rigid compared to previous erections.

Elongation and compression of the subtunical venules against the tunica albuginea are prerequisites for the veno-occlusive trapping mechanism necessary for erection. The ability to achieve maximal corporal volumes at low intracavernosal pressures is regulated by normal function of this outflow mechanism, a process that is dependent on the completeness of trabecular smooth muscle relaxation and the expandable mechanical properties of erectile tissue.

A functional venous leak may be induced by an increase in corporal smooth muscle tone from stress or anxiety. Similarly, increased trabecular connective tissue content secondary to chronic ischemia plays a central role in the pathogenesis of venous leak or venogenic ED. Ultimately, fibrosis of the erectile tissue causes decreased expandability of erectile tissue with subsequent poor stretching of the subtunical venules, poor venous outflow resistance, and failure to maintain penile rigidity. This pathology is most commonly associated with various systemic disease processes such as atherosclerosis. Direct corporal trauma from pelvic or perineal injuries, or from injuries to the penis while erect (fractured penis), may result in site-specific corporal fibrosis.

Diabetes Mellitus

Diabetes mellitus is a common cause of organic impotence. ED is reported in up to 75% of diabetic patients and occurs 10–15 years earlier than in the general population. Patients with insulin-dependent juvenile diabetes may have peripheral neuropathic impotence, with abnormal sacral evoked responses in 30 to 85% of patients. Those with non-insulin-dependent, adult-onset diabetes usually have vasculogenic impotence, but a combination of the neuropathic and angiopathic effects of diabetes is probably responsible for the dysfunction in most cases. Morphological alteration of the nerves, injury to the endothelium, as well as smooth muscle cell damage secondary to hyperglycemia have been shown. Diabetic patients have a marked increase in the threshold for response to vibrotactile stimulation.

Renal Failure

ED affects approximately 50% of dialysis-dependent uremic patients. Following renal transplantation, reversal of the chronic anemia, improvement in uremic neuropathy, or correction of abnormalities in zinc metabolism may result in improved erectile function. Hyperprolactinemia secondary to decreased clearance and increased production seen in end-stage renal disease has also been associated with erectile dysfunction.

Depression

A strong association between depression and ED has been demonstrated in a study in which, compared to men suffering from benign prostatic hyperplasia (BPH) alone, patients with ED were 2.6 times more likely to report depressive symptoms. In another study, Araujo *et al.* concluded that the relationship between depressive symptoms and ED in middle-aged men was statistically significant and independent of important aging and para-aging confounders such as demographic, anthropometric, and lifestyle factors, health status, medication use, and hormones. Despite these associations, a clear cause-and-effect

relationship between ED and depression has not been established.

Neurologic Lesions

Disturbances in the neural arm of the complex interaction between the vascular and neurologic events required for a normal erection can cause ED. This can occur at the following levels:

1. Intracerebral (Parkinson's disease, cerebrovascular events): Efferent pathways from the medial preoptic area or the hypothalamus may be affected.
2. Spinal cord (e.g., spinal trauma, multiple sclerosis, myelodysplasia): Cord lesions are the most common cause of neurogenic impotence. With injuries below T12, psychogenic erections may occur in approximately 25% of patients. Those with upper motor neuron lesions cannot achieve psychogenic erections. In general, approximately 30% of patients with cervical spinal cord lesions, 70% of patients with thoracic lesions, and 50% of patients with lumbar lesions are able to have erections. Patients with high cord lesions typically have short-lived erections that do not involve the corpus spongiosum and are non-ejaculatory. Sexual dysfunction may be seen in up to 75% of multiple sclerosis patients; in rare cases, ED may be the sole presenting symptom of multiple sclerosis. Reflexogenic erections, commonly seen in patients with upper motor neuron injuries, may occur following tactile stimulation below the level of the lesion.
3. Peripheral (e.g., iatrogenic, alcoholic neuropathy, diabetes): Damage to the cavernous nerves during radical pelvic surgery, such as radical prostatectomy, is not uncommon.

Endocrine Disorders

The reported incidence of endocrinopathy as the primary cause of ED ranges from 1 to 35%. Isolated testosterone deficiency is rare and is often accompanied by marked loss of libido. Interestingly, even among men with documented ED, the incidence of abnormally low serum testosterone levels has been historically small (6.6%). Despite the clear association of ED with aging, no consistent correlation of total testosterone levels with erectile condition had been identified. The serum testosterone level can affect sexual desire, frequency of nocturnal erections, and frequency of intercourse.

Other endocrinopathies with potential effects on erectile function include hypogonadotropic hypogonadism (Prader-Willi and Laurence-Moon-Biedl syndromes), hypergonadotropic hypogonadism (Klinefelter's syndrome, mumps orchitis, and surgical orchiectomy), and hyperprolactinemia (pituitary adenomas, craniopharyngiomas, or drug therapy).

Trauma

Pelvic fracture with ruptured posterior urethra and perineal trauma such as injuries associated with bicycle accidents are examples of injury-related ED. In pelvic fractures, damage to the neurovascular bundle, internal pudendal, or common penile arteries may lead to erectile pathology.

Postoperative/Iatrogenic ED

Aortic or peripheral vascular surgery may impair blood flow through the hypogastric arteries and thus cause arterial insufficiency. Occasionally, renal transplantation may cause ED, especially if a second contralateral transplantation is performed with end-to-end hypogastric artery anastomosis (impaired penile blood flow). In most instances, however, renal transplantation improves sexual function by reversing the chronic renal failure anemia and uremic neuropathy.

Vascular compromise as a cause of ED can also be seen after pelvic irradiation: accelerated occlusive atherosclerosis of the pelvic vessels, as well as fibrosis of cavernosal erectile tissue secondary to irradiation of the crural region, may contribute to postirradiation ED. Surgical (cavernosal-spongiosal) shunts to treat refractory priapism, certain neurosurgical procedures such as lumbar laminectomy, sacral rhizotomy, and pudendal neurectomy (especially if the sacral roots S2, 3, and 4 are injured), abdominoperineal resection of the rectum, and radical prostatectomy or cystoprostatectomy are also associated with postoperative ED.

Benign Prostatic Hyperplasia, Lower Urinary Tract Symptoms, and Erectile Dysfunction

A strong association between ED and lower urinary tract symptoms (LUTS) was shown in a study by Braun *et al.* in which 72% of men with LUTS had ED, whereas only 38% of those without LUTS had ED. In a study of 1274 European men, both ED and ejaculatory dysfunction were common and quite bothersome in those with LUTS. Ejaculatory function is increasingly regarded as a major contributor to the quality-of-life issues associated with sexual function.

Drugs and Medications

Various medications are associated with erectile dysfunction. **Table 1** lists some of these agents. A variety of medications and drugs have been found to cause drug-induced ED. Among the antihypertensive

Table 1 Partial list of medications that can cause erectile dysfunction

Centrally acting agents
α-methyldopa
Clonidine
Ethanol
Marijuana
Narcotics
Phenothiazines
Reserpine
Tricyclic antidepressants
Anticholinergic agents
Antihistamines
Antimuscarinic agents
Phenothiazines
Tricyclic antidepressants
Antiandrogenic agents
Cimetidine
Cyproterone acetate
Disopyramide
Estrogens
Ketoconazole
Spironolactone
Hyperprolactinemic agents
α-methyldopa
Estrogen
Haloperidol
Imipramine
Metoclopramide
Opiates
Phenothiazines
Reserpine
Sympatholytic agents
Alpha blockers
α-methyldopa
β-blockers
Bretylium
Guanethidine
Reserpine, clonidine
Agents with other properties or unknown mechanism causing ED
Digoxin
Epsilon-aminocaproic acid
Naproxen
Thaiazides

medications, thiazide diuretics and β-blockers are common culprits implicated in ED. Antipsychotic medications, tricyclic antidepressants, and the SSRIs have been shown to cause ED. However, in comparison to the other antidepressants, bupropion, an antidepressant of the aminoketone class, is relatively free of adverse sexual effects.

Evaluation

The ideal evaluation protocol is a biopsychosocial approach that encompasses the complete sequence of male sexual function: hypogonadism, ED, ejaculatory dysfunction, LUTS, and various psychosocial issues including depression, relationship factors, partner issues, and social stressors. The importance of gaining an insight into potential partner issues as a contributor to ED cannot be overemphasized.

Sexual History

The onset, duration, and circumstances of ED must be elicited. Questions are posed concerning erection quality during intercourse, masturbation, and nocturnal erections. Validated sexual questionnaires may be helpful tools in the evaluation of erectile function. Associated abnormalities (or changes) in ejaculation, libido, or orgasm should be noted. A psychogenic etiology is suggested by sudden onset of impotence or the presence of impotence under some circumstances, but normal erectile function at other times. A gradual deterioration of erectile quality with preservation of libido is more likely to be caused by an organic risk factor. Most patients with impotence can ejaculate despite poor-quality or absent erections.

Medical History

Inquiry is made about the patient's past and present medical problems, including diabetes mellitus, hypertension, smoking, hyperlipidemia, and liver, renal, vascular, neurologic, psychiatric, or endocrine disease. A history of abdominal, pelvic, or perineal surgery or trauma including possible bicycle injury is informative. Use of androgenic steroids and related substances by athletes mandates inquiries about these agents, as they are associated with decreased serum testosterone levels and decreased libido.

Psychological Evaluation

A brief psychosocial history is mandatory to gain insight into potential personal, interpersonal, social, and occupational roots of sexual problems. When deemed appropriate, an interview with a psychologist or sex therapist may be helpful to uncover personality disorders or the relation of psychological factors to ED (e.g., performance anxiety causing ED or organic ED leading to anxiety). The couple's expectations of the planned therapy are assessed.

Physical Examination

In addition to a focused examination of the genitalia, the general body habitus and status of secondary sexual characteristics should be assessed. The presence, size, and consistency of the testes are determined by palpation. The presence of small testes may suggest hypogonadism as a cause of ED. Gynecomastia may be present in patients with androgen deficiency or estrogen excess. Vascular insufficiency is

suspected with absent peripheral pulses in the lower extremities. Careful examination of the penis, including evaluation in the stretched and non-stretched positions is performed to assess adequacy of length, fibrotic plaques in the tunica albuginea (Peyronie's disease), or deformity of the corporal bodies. Pinprick testing of the penile and perineal skin may provide information about the sensory function of the pudendal nerve. Similarly, eliciting the bulbocavernosus reflex provides information about the integrity of the sacral reflexes. A digital rectal examination of the prostate to screen for prostate cancer is wise in men older than 50 (40, if African American or with a positive family history of prostate cancer).

Laboratory Tests

Hormonal status and evaluation of the integrity of the hypothalamic–pituitary–gonadal axis is performed by checking the serum testosterone, luteinizing hormone (LH), and serum prolactin levels. Standard serum chemistries, complete blood cell count, and lipid profiles may reveal vascular risk factors. The serum prostate-specific antigen (PSA) should be ordered in men over the age of 50 (40, if African American or with a positive family history of prostate cancer) to screen for possible prostate cancer. A higher incidence of prostate cancer in men with ED has not been demonstrated. Therefore, this test is done for routine male screening, rather than ED-associated prostate cancer screening. If both LH and testosterone levels are decreased, hypogonadotrophic hypogonadism is suspected and warrants consultation with an endocrinologist. If a low serum testosterone is confirmed, it is mandatory to check serum prolactin levels to rule out the presence of pituitary adenomas.

Specialized Diagnostic Testing

The need for specialized testing was dramatically changed by the introduction of sildenafil in 1998. As a general rule, although these diagnostic modalities help uncover pathophysiological mechanisms and further confirm the impressions discovered on the initial evaluation, their disadvantages, including cost and associated potential complications, have led to reduced indications for routine testing. Examples of tests performed by ED specialists include nocturnal penile tumescence (NPT) testing for a general assessment of organic vs. psychogenic ED, penile biothesiometry (vibration testing) for evaluation of the somatosensory pathway, and vascular testing (duplex Doppler ultrasonography, or, less frequently, dynamic infusion cavernosometry). Rarely, selective internal pudendal arteriography is indicated if arteriogenic ED is suspected in a candidate for microvascular arterial bypass surgery.

Treatment

Sex Therapy

Patients with evidence of psychogenic ED and no discernible organic cause should be encouraged to undergo a short course (6–12 weeks) of sex therapy with their partner. Professional evaluation of relationship distress, sexual performance concerns, and dysfunctional communication patterns is likely to enhance sexual function. In organic ED, behavioral sex therapy may be combined with various other forms of therapy in selected cases to optimize patient response. Performance anxiety may continue to play a significant role in a couple's sexual life after medical or surgical treatment; therefore, behavioral sex therapy must not be routinely abandoned in the presence of organic pathology.

Nonsurgical Therapy

Phosphodiesterase Type 5 (PDE5) Inhibitors Sildenafil, introduced in the United States in 1998, was the first US Food and Drug Administration (FDA)-approved phosphodiesterase type 5 (PDE5) inhibitor for the treatment of ED. Vardenafil and tadalafil are the other PDE5 inhibitors that have been approved for the treatment of male ED. All three are contraindicated in men who take any form of nitrates.

Sildenafil Sildenafil is a reversible inhibitor of PDE5. In response to sexual stimuli that activate the NO/cGMP pathway, inhibition of PDE5 leads to increased intracellular cGMP (decreased catabolism) and enhancement of cavernosal smooth muscle relaxation and erection. As with the other PDE5 inhibitors, it is taken on demand (prn). The recommended initial dose is 50 mg taken 1 h before sexual activity. The maximum recommended dose of sildenafil is 100 mg, no more than once per day, independent of the dosage used. Patients older than 65 years of age, those with renal or liver insufficiency, and patients receiving drugs that inhibit cytochrome P450 (erythomycin, cimetidine) should start with a 25 mg dose. Sildenafil inhibits PDE5 more selectively than many other PDE isozymes; however, it is only about 10 times more selective for PDE5 than for PDE6. This characteristic may be the basis for abnormal changes in color vision observed with higher doses or plasma levels of sildenafil. Sildenafil reaches maximum plasma concentrations within 30 to

120 min (median: 60 min) of oral dosing in the fasted state, but absorption may be reduced by a high-fat meal. The elimination half-life of sildenafil and its major active metabolite is approximately 4 h and no more than one dose should be taken per 24-h period. There is a 29% reduction in the maximum plasma concentration (C_{max}) when the drug is taken with a high-fat meal and the time to achieve the t_{max} will accordingly increase by 60 min. It is therefore recommended that sildenafil be taken on an empty stomach for optimal efficacy.

Sildenafil may be prescribed under careful medical supervision in patients who have suffered a cardiovascular event, myocardial infarction, or severe arrhythmia within the previous 6 months, or in patients with hypotension ($<90/50$), severe hypertension ($>170/110$), cardiac insufficiency, unstable angina, or retinitis pigmentosa. Sildenafil may be taken with caution in the following groups: patients receiving complex antihypertensive regimens; those with coronary artery disease, borderline blood pressure, or renal or liver insufficiency; and patients who use drugs that inhibit cytochrome P450. Sildenafil has been reported to improve significantly the symptoms of ED with varying etiologies and levels of severity; the postmarketing data are consistent with the results of the initial clinical trials. Sildenafil is reported to be effective and well tolerated in patients with a wide range of medical problems, including spina bifida, diabetes, cardiovascular disease (including those taking β-blockers, angiotensin-converting enzyme inhibitors, or calcium channel blockers) and those with parkinsonism.

Sildenafil should not be taken within 4 h after α-blockers. The most common side effects of sildenafil are headaches (16%), facial flushing (10%), dyspepsia (7%), nasal congestion (4%), and diarrhea (3%). Coadministration of sildenafil and nitrates (i.e., nitroglycerin, isosorbide dinitrate) is contraindicated.

Vardenafil Vardenafil is an FDA-approved, highly potent and selective inhibitor of PDE5 that demonstrates high bioavailability and rapid absorption. The median time to maximum plasma concentration of vardenafil is 0.6–0.9 h for all doses. Half-life is similar to sildenafil (i.e., approximately 4 to 5 h). C_{max} of vardenafil may be reduced by 20% following consumption of a high-fat meal (57% fat), but is unaffected by a meal of 30% (or less) fat. Vardenafil is contraindicated with the concomitant use of nitroglycerin or other organic nitrates. The bioavailability of vardenafil is increased by cimetidine and other cytochrome P450 inhibitors. A pivotal phase III study of the safety, tolerability, and efficacy of vardenafil as a treatment for ED in patients with diabetes mellitus reported intercourse success rates independently of HbA1c levels and of baseline ED severity.

Tadalafil Tadalafil is another FDA-approved selective PDE5 inhibitor for the treatment of ED. Perhaps the most distinguishing feature of tadalafil is its long half-life (17.5 h). Absence of significant food interaction and longer duration of efficacy have led to widespread public acceptance and capture of a significant global market share in a brief time frame. The results of at least two tadalafil studies indicate that, following a 20-mg dose, an erection can be achieved as early as 16 min and responsiveness lasts for up to 24 h, increasing spontaneity by enabling a man and his partner to have sex whenever they choose within at least a 24-h period. Others have found that tadalafil continues to enable men with ED to have sex as late as 36 h post dose.

In doses ranging from 2 to 25 mg, on-demand tadalafil was well tolerated and significantly improved erections in 81% of men with mild to severe psychogenic, organic, and mixed ED as compared with 17% of those who took placebo. Headache and dyspepsia were the most commonly reported adverse events. Most adverse events were mild to moderate in intensity and attenuated with further treatment. Myalgia is an uncommon adverse event that occurs slightly more frequently in association with tadalafil than with the other available PDE5 inhibitors. Tadalafil has a much higher selectivity for PDE5 than for the retinal enzyme PDE6, which likely explains why there were no visual changes associated with tadalafil in this and similar studies.

Yohimbine Yohimbine hydrochloride is an α_2-adrenergic blocking agent that was widely prescribed prior to the availability of the PDE5 inhibitors, but has not been shown to be more effective than placebo.

Vacuum Erection Device The vacuum erection device (VED), a non-invasive first-line therapy, has been approved by the FDA for over-the-counter distribution. The advantages of VED include simplicity of use, low cost, relative safety, and the ability to start treatment immediately. Patients with significant peripheral vascular disease are generally not good candidates for VED. The reported adverse events include difficulty with ejaculation, penile pain, ecchymoses, hematomas, and petechiae. Inconvenience, premature loss of penile tumescence and rigidity, penile pain, and pain during ejaculation have been reported as reasons for discontinuation.

Intracavernous Pharmacotherapy Most patients suffering from ED may potentially be treated with intracavernous injection of vasoactive medications. Safety and efficacy have been established in multiple studies, including those associated with the 1995 FDA approval of alprostadil (prostaglandin E1) as therapy for ED. Although penile self-injection therapy is highly effective (70–90%), there is a high dropout rate. Intracavernosal pharmacotherapy with vasoactive medications is contraindicated in patients on monoamine oxidase (MAO) inhibitors, patients with hypersensitivity to these agents, and those prone to secondary priapism (e.g., sickle cell disease/trait, leukemia, or multiple myeloma). Alprostadil alone or in combination with papaverine and/or phentolamine mesylate may be injected intracavernosally. Most studies show increased efficacy for the three-drug combination regimen compared to monotherapy. Onset of erection is usually around 10 min from the time of injection, and duration may range from 30 min to 6 h with the therapeutic goal of achieving an erection that is rigid enough for satisfactory vaginal penetration and lasts from 30 min to 1 h.

Priapism is an uncommon but potentially serious complication that can lead to permanent corporal fibrosis. Priapism of less than 24 h in duration can usually be managed without surgery by corporal aspiration and intracavernosal injection of α-adrenergic agents.

Transurethral Therapy

Alprostadil Intraurethral alprostadil is a relatively safe second-line therapy for the treatment of ED. In a double-blind, placebo-controlled study of 1511 men, 65.9% of patients had erections sufficient for intercourse, and 50% achieved successful intercourse in the home situation. A medicated pellet containing alprostadil is inserted intraurethrally with an applicator. Advantages include ease of delivery compared to intracavernosal injections. As a general rule, most specialists do not consider transurethral therapy to be as effective as intracavernosal injections. Penile pain and hypotension-related symptoms are the most frequently reported adverse events.

Surgical Therapy

Penile prosthesis surgery and microvascular arterial bypass surgery are the two main categories of surgical therapy for ED. Operations to reduce the venous outflow resistance (venous surgery) in patients with corporal veno-occlusive dysfunction have been performed but are generally unsuccessful and have not demonstrated long-term efficacy.

Penile Revascularization Microvascular arterial bypass surgery for ED (penile revascularization) is currently the only modality that has the potential to permanently cure patients. However, it is still considered experimental by the American Urological Association and is only performed in specialized centers with much experience. Most ideal candidates are young men with a history of perineal or pelvic trauma in whom arteriography reveals a localized common penile artery lesion. Those with generalized vascular pathology are poor candidates for this operation, since the same atherosclerotic pathology will likely affect the revascularization segment in the years following surgery. Revascularization is achieved by microsurgical anastomosis of the inferior epigastric artery to the dorsal penile artery. Appropriate selection of candidates for revascularization with adherence to strict criteria will yield excellent long-term patency and patient satisfaction when the operation is performed by an experienced microsurgeon.

Penile Prosthesis Surgery Penile prostheses are indicated for the treatment of organic ED due to a variety of causes. Most surgeons perform this operation as a last resort and recommend a trial of less invasive modalities including oral pharmacotherapy or intracavernosal injection before moving on to prosthesis surgery. There is a definite role for penile prostheses in the management of ED that is refractory to conservative measures. Even in the most challenging cases, experienced implant surgeons have reported successful prosthesis placement in severely fibrotic corpora by utilizing a variety of techniques.

Inflatable Prostheses Excellent functional and cosmetic results are achieved with multicomponent penile prostheses. Component inflatable prostheses consist of a pair of inflatable cylinders, a reservoir, a pump, and tubing to connect these components. The cylinders are implanted within the corpora, the pump within the scrotum, and the reservoir behind the rectus abdominis muscle in the perivesical space. Compressing the pump achieves active transfer of fluid from the reservoir into the cylinders. Pressing a release valve on the pump allows passive flow of fluid back to the reservoir and achieves detumescence. Significant design alterations over the years since the introduction of these prostheses have reduced mechanical failures and improved safety and efficacy such that they now compare favorably with non-inflatable rod-type devices.

Non-inflatable Prostheses Non-inflatable prostheses do not provide the cosmetic results provided by the multicomponent inflatable devices. However, the lower cost and relative ease of implantation make

them desirable in selected cases. The semirigid devices are typically made of pure silicone rubber that may be wrapped around a central coiled wire or have a core construction of articulating segments with metallic cables running through them. The polytetrafluoroethylene-coated rings are interlocked and connected by a spring-loaded cable, which can lock the rings in a straight column when activated and unlock for a relaxed flaccid state. Device chips and cracks may contribute to the failure rate of these implants, while the stiffer design may contribute to the higher rates of device erosion compared to inflatable prostheses.

See also: Depression; Sexuality, Sensuality, and Intimacy.

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Ethics and Euthanasia

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Glossary

Active Euthanasia – Acting to induce a patient's death.

Assisted Suicide – Providing a patient with the means necessary to end his or her life.

Involuntary Euthanasia – Ending a patient's life in violation of the patient's wishes.

Non-voluntary Euthanasia – Ending a patient's life without knowledge of the patient's wishes.

Passive Euthanasia – Refraining from acting to sustain a patient's life.

Voluntary Euthanasia – Ending a patient's life in accordance with the patient's wishes.

Introduction

'Euthanasia' means 'a gentle and easy death' or 'the means of bringing about a gentle and easy death.' In current usage, euthanasia refers specifically to active euthanasia, defined as performing an action intended to bring about a gentle and easy death. For example, a physician who administers a lethal injection for the purpose of ending a patient's life performs an act of euthanasia. Euthanasia as it is currently used can be distinguished from assisted suicide, which involves providing persons with the means necessary to end their own lives. Euthanasia also differs from what has historically been called 'passive euthanasia,' which involves refraining from an action, such as cardiopulmonary resuscitation, necessary to sustain a person's life.

Whether active or passive, when an effort is made to end another person's life, this effort may either conform to a competent patient's wishes (voluntary euthanasia) or violate a competent patient's wishes (involuntary euthanasia). A third possibility is that the patient's true wishes are not or cannot be known (non-voluntary euthanasia). This article reviews ethical considerations relevant to active voluntary euthanasia; it does not address related issues, such as assisted suicide and withholding and withdrawing life-sustaining treatment, in much detail. Unless otherwise noted, references to 'euthanasia' refer to voluntary active euthanasia.

Ethical Arguments Supporting Voluntary Active Euthanasia

Autonomy-Based Arguments

Ethical arguments supporting euthanasia often appeal to the ethical principle of autonomy, which requires respect for the voluntary wishes of a competent patient. According to one interpretation, a principle of autonomy requires others not to interfere with the autonomous choices of competent individuals. So, for example, a terminally ill patient who wishes to hasten death should not be prevented from doing so. A stronger interpretation of the principle of autonomy holds that we ought to offer positive assistance to competent individuals in their efforts to carry out their autonomous choices. According to this stronger interpretation, respect for patient autonomy lends support to taking positive steps to meet a patient's autonomous request for aid in dying, whether in the form of assisted suicide or euthanasia. Yet autonomy-based arguments for assisted suicide or euthanasia apply only to a limited group of persons, namely, persons able to form autonomous and voluntary preferences about terminating their lives.

These remarks make evident that when a principle of autonomy is interpreted as supporting euthanasia, it does not support hastening the death of someone who suffers from depression or other mental impairments that interfere with autonomy. Nor does euthanasia sanction terminating the life of a minor child. Arguments invoking autonomy also restrict assisted suicide or euthanasia to persons who are competent at the time assistance is requested, prohibiting such assistance when it is based on the prior request of a now incompetent patient. For instance, advocates of autonomy-based arguments do not generally support meeting a request for euthanasia from a person who is newly diagnosed with Alzheimer's disease and expresses through a living will a preference that her or his life be terminated in the future when mental processes deteriorate to the point that life is no longer worth living. Not only would it be difficult to apply a living will of this kind to specific situations, it has also been argued that in the case of severe dementia, the previously competent person is not the same individual as the later demented person to whom such a request would be applied.

Compassion-Based Arguments

Further support for euthanasia can be found by appealing to ethical considerations of compassion for the suffering of others. This approach calls attention to the fact that despite our best medical efforts, some patients suffer terribly at the end of life. For example, even when health-care providers can prolong life, they may be unable to alleviate a patient's pain and suffering without causing intolerable side effects. Under these circumstances, it has been argued that the only way to respond compassionately to suffering is to hasten a patient's death.

It is important to distinguish between acting for the purpose of relieving suffering, on the one hand, and acting for the purpose of causing death, on the other hand. Actions that hasten death do not always qualify as euthanasia, because euthanasia requires acting for the purpose of hastening death. Hence, a physician who administers a morphine drip in order to alleviate a patient's suffering does not perform euthanasia, even if the physician anticipates that morphine will gradually curtail a patient's breathing and cause death. Likewise, a physician who operates on a patient in order to restore function, foreseeing the possibility that complications of surgery may cause death, does not commit an act of euthanasia if the patient dies on the operating table. When supporters

of euthanasia invoke compassion-based arguments, they are not claiming that compassion justifies causing death, but that compassion justifies acting in order to cause death.

Appealing to compassion lends support to euthanasia only in a limited range of cases. Thus, arguments based on compassion do not give ethical warrant to ending the life of people who wish to die but are perfectly healthy and are not experiencing pain or suffering. Nor can compassion-based arguments justify terminating the life of permanently unconscious persons, because such persons do not experience pain or suffering.

Ethical Arguments Opposing Voluntary Active Euthanasia

Slippery Slope Arguments

In response to the preceding arguments, opponents of euthanasia hold that permitting one person to terminate another person's life will inevitably lead to various ethical abuses. One form this argument takes is called the psychological slippery slope. According to this line of reasoning, if persons begin to take human life in a certain limited class of cases, this will weaken their psychological inhibition against killing and lead to taking human life in other cases. For example, if society permits physicians to end the lives of competent patients who request to have their lives ended, in the future physicians will feel less averse to ending the lives of incompetent patients who are considered a financial or emotional burden on others. The soundness of this argument depends upon the truth or falsity of the empirical prediction it asserts.

Unlike the psychological slippery slope, the logical slippery slope argument does not rely upon a factual claim about the actual effects of permitting people to end others' lives. Instead, the logical slippery slope holds that persons who conclude that euthanasia is ethically permissible in certain cases are logically committed to holding that it is ethically permissible in other, more troublesome cases. For example, those who defend euthanasia by appealing to the ethical principle of autonomy will find it difficult to refuse to meet a request for euthanasia from a competent person who is perfectly healthy and 'tired of life.' If such a request expresses an autonomous decision, there appears to be no way to appeal to autonomy to forbid meeting this request.

Although appeals to compassion can justify refusing requests for euthanasia from healthy persons who are not suffering, opponents of euthanasia point out that compassion-based arguments are also vulnerable to slippery slope objections. This is because an appeal to compassion cannot be used to limit euthanasia to persons who are competent and request death. After all, the pain that an infant or mentally impaired person experiences presumably warrants no less compassion than the pain of a mentally competent adult.

By combining autonomy-based and compassion-based arguments, advocates of euthanasia can justify significant restrictions on euthanasia. However, certain restrictions remain difficult to support. Neither autonomy-based nor compassion-based arguments can justify restricting euthanasia to patients whose deaths are imminent. This is because people may autonomously choose to die even when they have many years ahead to live. And the prospect of suffering for a long time would appear to incite more, not less, compassion that then prospect of suffering for a few weeks or months.

Sanctity of Life Arguments

Another argument against euthanasia begins with the premise that human life in any form possesses an inherent worth and dignity. Hence, even when a person is suffering terribly or wishes to die, taking that person's life is wrong because it destroys something of immense value. According to this argument, the intrinsic value of human life is not contingent on whether a person's life is useful or subjectively valued. So, for example, even when disease renders someone unable to pursue life goals, that person's life continues to be valuable because the value of human life is intrinsic, not contingent on its results or accomplishments. Likewise, even when someone no longer values life and desires to die, ending that person's life would end something of value.

A principle ascribing intrinsic value to human life gains support from both religious and secular considerations. Whereas religious thinkers may argue that the value of human life stems from the fact that human beings are a divine creation, secular thinkers may argue for the value of human life on the ground that human beings are the highest achievement of an evolutionary process that took millions of years to unfold. Alternatively, rather than appealing to the historical origins of human life, support for the sanctity of human life may be based on comparing a future world with human beings to a future world without human beings. If most people prefer the former world to the latter world, it might be argued that most people implicitly accept the proposition that human life has intrinsic value.

Arguments opposing euthanasia that are based on the sanctity of human life present serious challenges to autonomy- and compassion-based arguments. Against autonomy-based arguments, this approach

suggests that even if a competent person prefers to die, ending life causes that person to lose something of value. Against compassion-based arguments, the sanctity of life principle implies that a life wracked with pain and suffering is still a life and therefore continues to be of great value.

The Practice of Voluntary Active Euthanasia

The paucity of empirical data on physician-assisted death makes it difficult to know how widespread the practices of euthanasia and assisted suicide are. Likewise, a dearth of empirical evidence makes it difficult to say how common alleged abuses of ethical guidelines governing these practices might be.

In the Netherlands, physicians have long practiced euthanasia and assisted suicide more openly than physicians in other societies do, and the practice of euthanasia was rarely prosecuted although it was until recently a crime. In 2002, the Dutch Parliament exempted physicians from criminal liability for practicing euthanasia and assisted suicide provided that certain conditions were met. These conditions include, for example, that the patient's request is voluntary, that the patient experiences lasting and unbearable suffering, and that the patient is informed about the situation and prospects and believes that there is no other reasonable solution. The law in the Netherlands also requires the physician to exercise due care in terminating life or assisting with suicide, including consulting with an independent physician who sees the patient and gives his or her written opinion. Despite these guidelines, empirical studies show that Dutch physicians sometimes act to end their patients' lives without discussing this decision with a patient, usually because the patient is incompetent and lacks the capacity to participate in such a discussion.

In the United States, the American Medical Association has taken a stand against 'the intentional termination of the life of one human being by another.' Nonetheless, public debate about physician-assisted death has arguably moved in the direction of greater tolerance for euthanasia. Although in 1950 only 34% of Americans supported euthanasia of incurably ill patients when both patients and families requested it, from the 1970s onward a growing majority of Americans have supported it. In 1991, for example, 63% of people in the United States supported euthanasia under these circumstances.

US law also appears to be moving in the direction of greater tolerance for assisted death. In 1994, for example, Oregon passed an initiative allowing physicians to prescribe, but not administer, lethal medication to competent, terminally ill patients who repeatedly request aid in dying. In the neighboring state of Washington, a US District Court ruled in the same year that a state statute making physician-assisted suicide a felony violates the US Constitution. These decisions may mark an important shift of legal and public opinion on this issue.

See also: Death and Dying; Ethics and Medical Decision-Making; Suicide.

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Ethics and Medical Decision-Making

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Glossary

Authenticity – Letting the patient be true to his or her own values.

Autonomy – Self determination especially regarding the integrity of one's own body.

Informed Consent – A shared interactive decision making process involving both the health care provider and the patient as full participants.

Materiality/Patient Oriented Standard – Disclosing to the patient any information that might make a difference in the decision-making reasoning of a reasonable, average patient in similar circumstances.

Reasonable Professional Standard – Disclosing to the patient the information that a reasonable, prudent physician would disclose to a patient under similar circumstances.

Introduction

Older individuals, most often in collaboration with their family members and friends, face a variety of important decisions at various points in their lives. These decisions concern multiple matters, such as financial planning and management, insurance, place and partners of residence, driving, activities, and the details of supportive services. Frequently, older persons are confronted with complicated medical decisions that arise in response to acute or chronic ailments (*see* Ethics and Euthanasia). The process of medical decision making may involve a number of ethical (as well as legal) considerations for the older person *qua* patient, relatives, friends, and health-care providers.

The ethical and legal implications of medical decision making overlap, but are not identical. They overlap both in the sense that ethical principles underlie legal doctrines (that is, we do legislate ethics all the time) and in the sense that the law generally sets the boundaries or parameters within which ethical decision making, based on a balancing of normative principles of right and wrong, must take place.

To a significant extent, the ethical (as well as legal) implications of medical decision making are generic, in the sense that they apply to adults of all ages. Principles and rules developed to deal with medical decision making for younger adults apply with full force to older persons, who do not lose their ethical standing or legal rights just because they have achieved older age. However, the patient's advanced years may in some instances raise issues that demand particular attention by the involved parties; this article tries to highlight such instances.

Informed Consent

An exploration of the ethical ramifications of medical decision making for all adult patients must begin with the doctrine of informed consent. Informed consent lies at the core of medical ethics today and in many ways has heralded the modern era in medical ethics. The informed consent concept originates with the principle of autonomy (self-determination, especially regarding the integrity of one's own body) and envisions a shared, interactive decision-making process involving both the health-care provider and the patient as full participants.

Informed consent is not a recently created idea. Plato referred to the requirement of informed consent to distinguish between the treatment of slaves and freemen. The informed consent concept was opposed by Hippocrates (in favor of physician-knows-best paternalism toward patients). Interest in the concept was renewed in seventeenth century European political philosophy, but opposition to it by the American Medical Association led to its dormancy in the American medical context until well into the twentieth century. Today, there is broad agreement in the United States that, in the arena of clinical medicine, informed consent is a concept essential to the American commitment to individual rights and an evenhanded relationship between patients and health-care providers. In addition to its foundation in autonomy, the informed consent doctrine has been justified by reference to the ethical principles of authenticity (letting the patient be true to his or her own values), privacy (the right to be left alone), beneficence (doing good for others), and nonmaleficence ("First, do no harm").

It is important to note that commitment to the informed consent doctrine and its ethical predicates is not universal. In numerous other cultures, the process of medical decision making is driven by other, opposing values, such as medical paternalism or a belief that families, rather than individual patients, ought to make the decisions. Professional caregivers in the United States must be sensitive to

these cultural considerations, which may be particularly strong for older, especially immigrant, patients and their families.

In their legal formulation, the substantive components of the informed consent doctrine have evolved on a case-by-case basis as a matter of individual state common (judge-made) law. Additionally, the majority of states have enacted statutes and/or promulgated regulations enumerating their jurisdiction's specific details regarding informed consent, for clinical care generally and/or within particular settings such as nursing facilities or public mental institutions.

The doctrine of informed consent applies to diagnostic and therapeutic medical interventions, as well as research-related activities involving a patient's participation (discussed later). For a patient's decision about a medical intervention to be considered ethically and legally valid, three interrelated but separate elements must be present. First, the patient's participation in the decision-making process and the final decision regarding intervention must be voluntary – that is, not unduly dictated by force, fraud, duress, or other real or threatened ulterior form of constraint or coercion. Second, the patient's agreement must be properly informed. Before proceeding, the health-care professional is obligated to disclose sufficient information about the proposed intervention to empower the patient to make a knowledgeable, intelligent consent or refusal. The third essential element of legally valid consent is that the patient presently be cognitively and emotionally able to understand and manipulate pertinent information in order to make effective choices concerning personal medical care.

In terms of the informed component of the informed consent doctrine, there are two competing standards for determining how much information about a proposed medical intervention must be shared with the patient beforehand. The medical custom or reasonable professional standard asks what information a reasonable, prudent physician would disclose to a patient under similar circumstances. By contrast, the more recently developed materiality/patient orientation standard asks what information might make a difference (that is, might be material) in the decision-making reasoning of a reasonable, average patient in similar circumstances.

The philosophical rationale, promoted by patients' rights advocates, for the progression in informed consent doctrine in close to a majority of jurisdictions from a reasonable physician to a patient-oriented standard of information disclosure is the belief that the latter approach better promotes the ethical ideal of patient autonomy, while the former approach reinforces the negative practice of physician paternalism that tends to impinge on patient autonomy. There is a fundamental distinction between the two approaches. Physicians make treatment decisions based on their calculations of likely patient benefit, as affected by the particular personal characteristics of the patient being treated. Patients, by contrast, focus on the personal consequences of a decision, especially the risks and costs associated with various ways of addressing their health problem. Under the autonomy principle, the factors most important to the patient must guide the decision calculus.

Under either the materiality or reasonable physician standard, the basic elements of information disclosure included within the health-care provider's fiduciary or trust obligations to the patient clearly include the following: diagnosis or nature of the problem; nature and purposes (that is, expected benefits) of the proposed intervention; reasonably foreseeable risks associated with the intervention, specifically, their likelihood of happening and potential severity if they do materialize; reasonable alternatives and their benefits and risks; and (because there is a recognized right of informed refusal) the probable risks and benefits of not undergoing the proposed intervention.

There are other informational items that some ethical commentators and courts have argued ought to be included as a necessary part of the informed consent process. These include complementary and alternative medicine alternatives, which are increasingly popular with older individuals; the cost implications of the proposed intervention for the patient (an item of importance especially to many older persons); the particular provider's personal experience and success rate with the specific intervention recommended; other provider-specific information; the provider's financial incentives arguably impacting the patient's care; the level of uncertainty in the medical community regarding the particular intervention; and the role, if any, that defensive medicine considerations are playing in the health-care provider's treatment proposal.

When informed consent to particular medical interventions is indicated by the spoken or written words of the patient (or the patient's legally authorized surrogate, as discussed later), the consent is characterized as express. However, there are many situations in which the patient's permission does not need to be put into words, but instead may be implied from the totality of the circumstances. This occurs when, through actions, the patient signifies a wish (or at least a willingness) to receive the specific intervention by voluntarily submitting to it in a way that the health-care professional can reasonably rely

on to conclude that the intervention has been authorized. Implied consent is appropriate for most routine, non-risky, non-invasive kinds of medical interventions. It is not an exception to the general informed consent doctrine; it is just a different (created by behavior instead of words) form of permission.

Express consent is more appropriate when the proposed medical intervention is intrusive and/or significantly riskier than ordinary, everyday life. With a very few exceptions created by particular state statutes for certain kinds of interventions (such as testing for the HIV virus or AIDS), express consent in the form of spoken words by the patient is quite ethically and legally adequate, as long as it is voluntarily and competently given on the basis of sufficient information. For particularly intrusive or risky interventions, the health-care provider may choose to document the patient's consent by requesting that the patient sign a separate piece of paper labeled a consent form, in addition to making a progress entry in the patient's medical record. Voluntary accreditation standards with which the provider complies, such as those of the Joint Commission on the Accreditation of Healthcare Organizations, may require the use of separate written consent forms for particular categories of medical interventions.

Patient Incapacity and Surrogate Decision Making

Usually, the health-care provider is obligated to discuss all relevant information and negotiate diagnostic and treatment plans directly with the patient. Sometimes, though, the patient is not mentally capable of assimilating pertinent information and engaging in a rational, voluntary decision-making process about the proposed and alternative medical interventions. This situation is likely to occur in the case of older persons who have impaired cognitive or emotional capacity as a result of a dementia, depression, or other age-related mental disorder. It makes little sense to talk about autonomous decision making by individuals who do not have the ability to act autonomously. However, when the patient personally lacks adequate decisional capacity, the health-care provider is not relieved of the duty to dispense with informed consent; rather, the provider must work with someone else who is willing and able to act as a surrogate or proxy on the patient's behalf.

Assessing decisional capacity in older persons may be a particularly complex and difficult task, and no simple mechanical capacity-measuring device has been invented yet to make the exercise automatic. Nonetheless, certain general guidelines for conducting this type of assessment may be delineated.

The ethical principles of autonomy and beneficence are not best served when capacity is determined on the basis of the patient's clinical diagnosis or category, or on the basis of agreement with the wisdom of the patient's specific choice of treatment, and certainly not when a determination of incapacity is based simply on the patient's advanced years. Rather, the focus should be on the patient's functional ability – that is, on the thought processes undertaken in arriving at the patient's good or bad decision.

In such a functional inquiry, among the basic questions to be asked are the following: (1) Can the person make and communicate (in any understandable form) any decisions at all? (2) Is the person able to offer reasons for the choices made, indicating that some degree of reflection and consideration were exercised? (3) Are the reasons cited as underlying the individual's choices based on logic and factually accurate suppositions? For example, in one case an older woman who refused to consent to amputation of her gangrenous leg, because she denied the existence of any medical problem other than dirt on her leg that could easily be washed away, was properly deemed to be incapacitated from making her own autonomous medical decisions. (4) Can the patient appreciate the ramifications (that is, the likely risks and benefits) of the options presented and the choices expressed, and the fact that these ramifications apply to that patient? (5) Does the individual, in fact, comprehend the implications of his or her choices?

A patient's current cognitive and emotional capacity needs to be assessed on a decision-specific basis; in other words, an individual may be capable of making some decisions (such as whether or not to follow a low-salt diet) rationally, but not other decisions (such as whether or not to undergo bypass surgery). Thus, capacity should not be treated as a global, all-or-nothing matter applicable to all decisions. Partial or limited capacity is possible. The question is whether the patient is capable enough to make the particular decision in question.

In addition, capacity may fluctuate within a specific patient according to variables such as time of day, day of the week, physical location, acute and transient medical problems, other persons available to support or coerce the patient's choice, and medication reactions. Older individuals may be especially vulnerable to fluctuations in capacity induced by these factors. In many cases, some of these factors may be susceptible to manipulation by caregivers so that discussions with the patient about care can take place under the most lucid circumstances possible. When feasible, health-care providers should try to maximize the patient's ability to participate in

medical choices (for example, through changes in the timing of drug administration) before they turn to a surrogate acting on behalf of the patient.

There are certain mechanisms available to maximize one's prospective autonomy. The older person (although this is not restricted to older persons) may use legal advance planning instruments to take steps, while still mentally capable, to anticipate and prepare for eventual incapacity by voluntarily delegating or directing future medical decision-making authority. The durable power of attorney consists of a written document in which an individual (the principal) may appoint an agent, or attorney-in-fact, to make future decisions (including medical decisions) for the principal. Every state has enacted one or more statutes that explicitly authorize the use of a durable power of attorney to empower the agent to make medical decisions on the patient's behalf, should the patient lose decision-making capacity.

Several ethical principles form the foundation for such legislation. Autonomy, as observed earlier, is the precept that individuals ought to have control and integrity over what happens to their own bodies. To exercise autonomy in the medical decision-making sphere, the patient needs information about alternatives and potential outcomes. In the case of mentally incapacitated patients, the patient's autonomy is best served by informing a surrogate (ideally one chosen by the patient) of the patient's own preferences and then expecting that surrogate to make specific clinical decisions based on the patient's substituted judgment (namely, choosing what the patient would choose if contemporaneously able to make and express personal decisions).

Durable powers of attorney fall into two categories. An immediate power comes into effect as soon as the agent is named. By contrast, in a springing power, the legal authority transfers (springs) from the patient to the agent only on the occurrence of some specified future event, such as declaration of the principal's incapacity by a designated number of examining physicians. The patient should be informed by attending health-care providers when they have decided to act as though decision-making authority has sprung to the designated agent, so that the patient can utter a protest, if desired, to the agent's power.

The durable power of attorney, which is a proxy directive, is distinguishable from a living will, which is an instruction-type directive. In the latter device, a competent patient documents his or her wishes regarding future medical treatment rather than naming an agent to make future treatment decisions in the case of incapacity. These two kinds of legal devices are not mutually exclusive, and patients may be encouraged to execute them in tandem because the living will can help an agent named under a durable power of attorney to exercise the patient's substituted judgment more accurately (*see* Ethics and Euthanasia).

When a patient is decisionally incapable but has not previously executed a living will or appointed a health-care decision-making agent, in a majority of the states, health-care providers may rely on legislation empowering family members and specified other persons to make medical decisions for incapacitated persons. In states that have enacted family consent statutes, the approved procedure ordinarily consists of documenting unanimous agreement among the attending physician, specified relatives or others (listed in a stated order of preference), and sometimes consultant physicians as well. The legislative trend in this direction was fueled by the United States Supreme Court's decision in *Cruzan* (1990), holding that the extent and conditions of proxy (including family) medical decision-making authority are a matter of state legislative, rather than federal constitutional, policy. In almost all of the states without family consent statutes, courts nonetheless recognize as a matter of common law or the state's own constitution the family's authority to exercise the incapacitated patient's decision-making rights on his or her own behalf. Most of these cases establish legal precedent for other families to act in other, future cases without the need for prior court approval.

When there is no durable power of attorney, family consent statute, or judicial precedent empowering the family to act, or in those relatively rare circumstances in which family members strongly and irreconcilably disagree about the best course of care for their decisionally incapacitated loved one, creation of a guardianship or conservatorship may be advisable to transfer decision-making power officially from an incapacitated patient to a proxy. However, the formal legal process (with its attendant financial, time consumption, and emotional costs) should not be initiated unless and until extralegal approaches, such as mediation or the involvement of an Institutional Ethics Committee, have been attempted in an effort to reach a sufficient level of harmony among all the interested stakeholders.

The guardianship/conservatorship process, when as a last resort it becomes necessary, entails appointment by a state probate court of a surrogate (the guardian or conservator) who is authorized to make certain decisions on behalf of a decisionally incapable person (the ward), ordinarily in response to a petition filed by the family or a caregiver. This appointment is combined with a review by the probate court of the sworn affidavit or live testimony of a physician who is familiar with the patient.

This form of intervention usually is benevolently inspired, as translated into the state's inherent *parens patriae* legal power to protect the vulnerable from harm. Nonetheless, because creating total (plenary) guardianship usually involves extensive deprivation of an individual's basic decision-making rights, the least restrictive/least intrusive alternative doctrine makes a limited guardianship preferred whenever feasible. Under this autonomy-inspired doctrine, the state should deprive individuals of their rights only in the least intrusive or least restrictive manner available, consistent with the legitimate social goal of protecting the individual against harm. Probate courts possess the authority to limit the proxy's power to decide only those particular types of decisions the ward personally is incapable of handling rationally.

Traditionally, the guardian has been required to make decisions consistent with the guardian's view, as a trust agent, of the patient's best interests. Many states still expect guardians to act according to the best interests standard. The modern trend in proxy decision making, though, has been toward enforcement of a substituted judgment standard. Under this approach, as previously explained, the guardian is obligated to make those decisions that the patient would make, according to the patient's own preferences and values to the extent that they can be accurately ascertained, if the patient were presently able to make and express competent decisions.

Decisions Concerning Participation in Research

Thus far, the discussion has concentrated on the ethics of making decisions when the medical interventions proposed are intended and expected to benefit the diagnostic or therapeutic treatment of the particular patient involved. However, sometimes an older person is asked to participate as a human subject in a biomedical or behavioral research protocol entailing an intervention (experiment) whose primary aim is to systematically collect data from which generalizable conclusions may be drawn that the investigators hope will benefit other people (whose identity is presently unknown) at some point in the future. An important secondary aim of a treatment research protocol may be to benefit the present participants (for example, in cancer drug trials when standard treatment has failed or does not exist), but the participants' main role in this research situation still is as a source of data.

Because participation in research protocols, no less than in the diagnostic or therapeutic context, ordinarily requires the voluntary, informed, and competent consent of each participant, there is a general ethical consensus that, whenever feasible, researchers should enroll only those participants who themselves are able to give or deny consent to participation. In other words, individuals with seriously compromised decisional capacity should be considered for recruitment only for those research protocols that are devoted to studying problems specific to the decisionally compromised population.

The disproportionate prevalence of dementias and other severe mental disabilities among the elderly presents a legal and ethical dilemma when research does specifically address the problems of the cognitively and emotionally impaired. On the one hand, progress in developing effective treatments and cures for medical and psychological problems associated with dementia requires that research projects be done in which individuals suffering from the exact problems of interest be the basic units of study. At the same time, paradoxically, those very problems that qualify an individual for eligibility as a subject in such a research project often make it impossible for that person to engage in a rational and autonomous decision-making process about his or her own participation as a research subject. This irony is made more difficult by the fact that research participants generally are more vulnerable to possible exploitation, and therefore need even more protection, than patients in therapeutic situations because of, among other things, the researchers' potential conflicts of interest.

Federal regulations covering biomedical and behavioral research require that informed consent for participation be obtained from the "subject or the subject's legally authorized representative" (45 Code of Federal Regulations Sec. 46. 116). However, a subject's legally authorized representative is defined in circular terms to mean an "individual or judicial or other body authorized under applicable [presumably state] law to consent on behalf of a prospective subject" (45 Code of Federal Regulations Sec. 46. 102(0)). Thus, state law, even when ambiguous or unspecific, controls in this arena.

A number of alternative mechanisms for proxy decision making in the research context are possible. These devices include a durable power of attorney for research participation, reliance on family consent statutes, informal resort to available family members as surrogate decision makers, guardianship with specific authorization for research decisions, explicit prior court orders authorizing the incapacitated subject's participation in research protocols on a case-by-case basis, an independent patient advocate supplied by the organization sponsoring the research or by a government agency, and selection of a surrogate

by the institutional review board (IRB) or a long-term care facility's resident council.

In making decisions about whether to enroll a decisionally incapacitated elder in a biomedical or behavioral research protocol, a proxy ideally will be guided by the substituted judgment standard, which entails knowing or being able to reasonably infer whether the incapacitated person him- or herself would have elected to participate, if that person were now able to make and express his or her own autonomous choice. When applying the substituted judgment standard is not reasonably feasible, because there is no realistic way to know or infer what the incapacitated individual would authentically desire regarding enrollment in a particular research protocol, rather than engaging in unbridled speculation about those desires, the proxy should perform a best interests analysis. In determining the incapacitated person's best interests regarding possible research participation, the proxy should take into account (among other things) the ratio of likely burdens or risks for the research participant versus the possible benefits to that person and others now and in the future emanating from the research findings.

Some have suggested that special procedural safeguards are necessary to protect vulnerable, cognitively impaired human volunteers from injury due to research participation. These safeguards might encompass heightened IRB involvement in the protocol approval process, enhanced IRB activity in the ongoing monitoring and supervision phase of the research, including serving as a forum for appeals and objections by participants or investigators, and requiring individual participant assent (that is, giving participants a veto power) even when informed proxy consent to research participation has been obtained. An important question, especially since the participants of interest are mentally impaired, concerns the definition of assent to be used, namely, whether the failure to actively object to participation in a protocol is enough to be interpreted as an implied form of assent, or whether some more positive manifestation of agreement is necessary.

Summary

Older individuals, or those authorized to speak for them, are likely to confront a panoply of decisions about consent to or refusal of offered diagnostic, therapeutic, and research interventions intended to address acute or chronic medical conditions. The complexities of medical decision making by and for older persons engender challenges implicating the sometimes conflicting ethical principles of autonomy, beneficence, non-maleficence, and social or distributive justice. The individual, family members, health-care providers, clinical investigators, and agents of society all have a significant role to play in promoting the decision-making rights of older persons while protecting them by attempting to maximize their benefits and minimize their exposure to harm.

See also: Caregiving and Caring; Dementia; Ethics and Euthanasia; Health Care and Services.

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Ethnicity and Minorities

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Glossary

Ethnic Groups – Social groups that are distinguished on the basis of national origin, culture, or religion.

Racial Groups – Social groups that are distinguished on the basis of physical factors such as facial features or skin color and that are used to restrict access to valued resources or power.

Introduction

Gerontologists have been giving increased attention to the heterogeneity of the aged population, especially with respect to race and ethnicity. This interest is based to a large extent on the tremendous growth in the numbers and proportions of people of color and diverse ethnic origins in the United States, Canada, Australia, and the United Kingdom, as well as in other Western societies. In the United States, non-Hispanic Whites accounted for 88% of the 65 and older population in 1980. This figure dropped to 83% in 2003 and is projected to be only 61% by the year 2050.

Although African American elderly are the largest component of the minority elderly population, they are projected to show only modest increases in their numbers in the foreseeable future. On the other hand, Hispanic elderly should outnumber African American elderly by the year 2020, and one in six elderly Americans are expected to be of Hispanic origin by the year 2050. The fastest growing segment of the elderly population is Asian and Pacific Islanders, who are expected to grow from 2% of the older population in 1995 to almost 8% by 2050.

What is often neglected both by researchers and policy makers is the great diversity within the above ethnic categories, especially among Hispanics and Asian Pacific Islanders. In 2004, for example, 51% of Hispanic elderly were of Mexican origin, 16% Cuban, 12% Puerto Rican, and 20% Central American and other Hispanic. Because of immigration patterns, the next generation of Hispanic elderly (those currently ages 55–64) will be increasingly Mexican and decreasingly Cuban. Although Hispanics share a common linguistic background and the overwhelming majority are Roman Catholics, they nevertheless vary widely in such characteristics as education levels, poverty status, geographic concentration, and immigrant status. There is similar diversity among older Asians. In 2000, 30% were of Chinese origin, 21% Filipino, 18% Japanese, 10% Asian Indian, 8% Korean, and 7% Vietnamese. Future generations of Asian elders will be increasingly Vietnamese and Asian Indian and decreasingly Japanese. Asian and Pacific Islanders are from a variety of linguistic, religious, and cultural backgrounds. Finally, American Indians originated from roughly 500 tribes that differed in cultural, social, and economic characteristics. In addition there is substantial ethnic diversity in the non-Hispanic White elderly population, which remains understudied and underappreciated.

Research on ethnicity, race, and aging can be separated into ethnogerontology and minority aging studies. Ethnogerontology studies how the aging process is shaped by culture and the beliefs of groups, including Italian American elderly and Jewish elderly as well as Hispanics and African Americans. Minority aging studies focus on the groups defined by the

US. Census that have been the targets of social exclusion in recent history (Hispanics, African Americans, Asian Americans, Pacific Islanders, American Indians/Alaska Natives). Ethnogerontology has a stronger focus on diversity in aging, while minority aging studies have a stronger focus on disparities in old age.

The growing size of older racial and ethnic populations in the United States poses challenges to both gerontologists and policy makers. This article provides a brief overview of what is known about the status and well-being of America's racial and ethnic minority elderly, focusing on such important areas as physical health, mental health, social relationships, and economic status, principally from a minority aging studies focus. It begins by outlining a historical overview of the field of ethnic and minority aging and conceptual approaches to studying ethnic diversity.

Studying Ethnic and Minority Populations

Much of the field of gerontology has grown without adequate attention to the population's racial and ethnic diversity. Serious attention was first given to aging among African Americans in the 1960s, when advocacy groups highlighted the disadvantages in health, income, life satisfaction, and housing for older African Americans by applying the concept of double jeopardy. Attention to Hispanics, mostly Mexican Americans, began in the 1970s, and it was not until the 1980s that Asian and Pacific Islanders, American Indians, and European-origin ethnic groups began to receive substantial attention in the gerontological literature. The last three broad categories continue to be understudied. Aging among ethnic and minority populations is also receiving increasing attention in other Western countries.

Inequality has been a core concept in the study of racial and ethnic elderly, usually in comparison to White elders. The popularity of the double jeopardy hypothesis in the 1970s and 1980s emphasized the larger multiple hierarchy stratification system in the nation. Although differences between minority groups and the majority are clearly evident, differences between groups in health, income, and psychological well-being have not typically been found to increase with age. This may be due to higher early mortality in disadvantaged populations, which leads to greater selective survival into old age. It may also be due to the lower starting point in the health and wealth of minority populations, which leaves them less room for decline than in the majority population (called floor effects in statistics).

There has not been any conceptual framework that has become popular in studies of racial and ethnic elderly since double jeopardy was discarded in the 1990s. Instead, the field has continued to be dominated by a services-oriented problem focus with a tendency to emphasize disparities. The literature on aging in minority populations is dominated by research on health status and health services, including issues such as caregiving. There is less research on issues related to income, housing, and transportation. The field only occasionally draws on concepts and approaches from related disciplines, such as social capital, globalization, racialization, cultural studies, network analysis, and feminist theory. This is likely the result of much of the research being conducted in professional schools and programs, with academic departments paying limited attention to race and ethnicity as it involves the older population.

Research on disparities in the older population continues to grapple with the question of the extent to which health differences are the result of race or ethnicity per se, or whether those social categories are simply proxies for economic and educational differences between populations. Work that focuses on the diversity of values and ideas about health and the treatment of disease commonly adopts a more ethnographic type of approach of describing the variations to increase awareness of different worldviews. When work on ethnicity takes a comparative approach, there is a heavy emphasis on acculturation.

Physical Health

Mortality and Life Expectancy

The most common indicators of health differences employed in the literature have been mortality rates and life expectancy figures. Mortality rates for African Americans have consistently been worse than those for non-Hispanic Whites, although the gap has steadily declined throughout the last century. Figures for Hispanics, American Indians, and Asian Americans no longer support a disadvantage of these groups, especially among people of Asian origin, who are estimated to have a life expectancy at birth of 83 years. However, the quality of mortality estimates for these groups is more questionable than the quality of estimates for African Americans and non-Hispanic Whites. This is especially the case with the American Indians; misclassification of ethnicity on death certificates leads to significant underestimates of mortality rates for this population.

African Americans have historically had higher mortality rates than Whites. These differences decline with age, to the point of a reversal at very advanced ages. The age of this mortality crossover

has been slowly rising over the years. If the crossover is the result of selective survival, as many argue, the rising age of the crossover suggests that the relative health of African American elders is improving and that they are receiving better medical care when they do fall ill. It does not mean that health disparities in old age are about to disappear, but it does suggest movement in a positive direction.

Although the accuracy of the estimates of the life expectancy of Hispanic populations has been questioned, accumulating evidence over the past 25 years suggests a Hispanic life expectancy at birth that is at least equal to that for non-Hispanic Whites. This has been observed for all three major Hispanic populations: Mexican Americans, Cuban Americans, and Puerto Ricans. This is considered an epidemiological paradox because Mexican Americans and Puerto Ricans have much lower mortality overall and for key conditions such as heart disease and cancer than would be expected given their overall risk factors, such as low incomes, low education, low rates of health insurance, and disproportionate employment in hard and dangerous occupations.

The apparent favorable mortality profile of Hispanics has been attributed to protective cultural factors, selective immigration, and selective return migration. Protective cultural factors include healthier diets, lower rates of tobacco and drug abuse, and stronger social ties. Selective immigration is supported by recent data that suggest that immigrants at any age are healthier than those who remain in their home country. At the same time, there are recent studies that indicate, at least among Mexican Americans, a 'salmon bias,' or return migration to Mexico of less healthy Mexican-origin persons, which may account for much of the mortality advantage of Mexican Americans. Selective immigration may very well be the prime reason behind the favorable mortality situation of most Asian-origin populations. Selective Asian immigration both selects healthier individuals to come to the United States and selects those with technical skills that are in high demand, contributing to a relatively favorable economic situation of most Asian origin groups. The starkest exception to this favorable health and sociodemographic trend is the Hmong, who fled a war-torn country over a short time period with few skills outside of agriculture.

Official estimates of the life expectancy of the American Indian population suggest that it has increased to the level of the general population, although again these estimates are based on data of questionable quality. The misclassification of ethnicity on death certificates seriously underestimates American Indian mortality rates. At a minimum, American Indians have exhibited remarkable progress in recent decades owing a great deal to the success of the Indian Health Service in controlling infectious diseases and providing acute care.

Morbidity and Functional Health

Mortality is often used to describe the health of populations because the government collects data on all deaths, providing a useful data source over time and across populations of varying sizes. But death is a rather crude indicator of health. Data on the prevalence of chronic conditions and disabilities provide a better insight into the health of populations.

Good sample-based population data have been regularly collected on several groups of racial and ethnic elderly for the past 15 years. National data are collected by a number of both longitudinal and cross-sectional national surveys and are complemented by several population-specific longitudinal surveys such as the Hispanic Established Populations for Epidemiologic Studies of the Elderly. Older African Americans consistently show higher rates than non-Hispanic Whites of major health conditions, including hypertension, diseases of the circulatory system, and diabetes. They also have the highest rates of functional limitations, both upper body and lower body. While the gap in disease and disability rates diminishes when Black–White population differences in wealth and other socioeconomic characteristics are controlled, most studies continue to find that race has some independent effect that leads to poor health. This may be the result of the stress and social exclusion associated with race, across socioeconomic status, in the United States (*see* Epidemiology).

Hispanics present a more complex pattern of disease and disability in old age. The favorable mortality situation of Hispanics does not fully translate into a favorable morbidity situation, but the picture here is not very clear because of variable quality and scope of data. Most evidence suggests that Hispanic men have a lower prevalence of heart disease and major cancers, but it is not clear why. With the exception of Cuban Americans, Hispanics are clearly disadvantaged socioeconomically, have very high rates of diabetes and obesity, and engage less in exercise. In addition, recent data from a large study of Mexican American elderly show that hypertension is at least as prevalent among them as it is among the general elderly population. Smoking and alcohol consumption rates among Hispanic males are also high. Any advantages in diseases of the heart and cancer among Hispanic males cannot be explained by known risk factors and may very well be related to selective immigration (*see* Alcohol and Drugs; Cardiovascular System; Cancer and Age).

In contrast, diabetes rates are considerably higher in Mexican American men and women than in non-Hispanic men and women at any age. Recent data on Mexican American elderly show that both male and female diabetes rates decline significantly from ages 65–74 to ages 75 and over, a situation that is not present among non-Hispanic Whites. This underscores the great negative consequences of diabetes in early old age among Mexican Americans and the high rates of mortality associated with it. A similar pattern for diabetes is observed among African Americans, who also have high rates of diabetes.

Disease rates for Asian American elderly overall are similar or better than those of non-Hispanic Whites. There are less data for this population because of their relatively small population size and their geographic concentration, often resulting in insufficient sample sizes for analysis from national surveys. Another limitation of national surveys is that they rarely collect data in Asian languages, and the majority of older Asian Americans (with the exception of Japanese Americans) are limited-English speakers. Data from the California Health Interview Survey, which included interviews in Mandarin, Cantonese, Vietnamese, and Korean, show older Asian Americans overall with a higher rate of diabetes than non-Hispanic Whites, although it is lower than the rates for the other minority groups. Other conditions, including heart disease, stroke, and cancer, have rates similar to or lower than those of non-Hispanic Whites. The variation within the older Asian population is evident in California, where Filipino American elders have higher rates of heart disease and arthritis than the other Asian subgroups.

In addition to mortality and disease prevalence, functional health is important among the elderly because it affects their ability to live independently. African Americans consistently have the highest rates of disability across all measures and have the highest rates of retiring from work because of disability. This may be related to their higher rates of chronic diseases and the severity of those conditions, their lower overall socioeconomic status, and/or the worse medical care they receive for a variety of chronic illnesses.

Recent data suggest that the functional health of Mexican American elderly, in terms of needing assistance with activities of daily living (ADLs), appears to be better than the functional health of African American elderly but slightly worse than non-Hispanic White elderly. With respect to four instrumental ADLs (IADLs) (meal preparation, shopping, using the telephone, and performing light housework), elderly Mexican Americans appear to be more impaired than either non-Hispanic Whites or African Americans (*see* Disability, Functional Status and Activities of Daily Living).

Diversity in functional status has been observed across elderly Hispanic subgroups. In one study, older Cuban Americans were found to have the lowest rates of limitations in ADLs and IADLs, while Puerto Ricans reported the highest rates. Older Mexican Americans had rates of limitations similar to Cuban-origin elders for ADLs but similar to Puerto Ricans for IADLs. The prevalence of functional limitations among these groups confirmed that their functional health tends to be worse than that of the general population of elderly persons.

The poorer functional health of African American, Mexican American, and Puerto Rican elderly is consistent with data on self-assessed health, which show poorer self-assessments than in non-Hispanic White elderly. In light of the socioeconomic, health, and access to care disadvantages of minority elderly, the poorer self-assessments appear to be realistic and not pessimistic because of the socioeconomic and cultural factors that predispose them to report poorer health.

There are limited data about the functional status of Asian American and American Indian elders. Pooled data from the National Health Interview Survey suggest that activity limitations for older American Indians are as high or higher than those of older African Americans, and remain higher than those of non-Hispanic Whites even after controlling for income, education, gender, and age. The same data show significantly lower rates of activity limitations for Asian American elders, with the caveat that the respondents to this survey exclude most Asian-language limited-English speakers. Data from the California Health Interview Survey, which includes several Asian languages, show a similar pattern of advantage for Asian Americans' rates of needing assistance with ADLs compared to non-Hispanic Whites.

Mental Health and Psychological Well-Being

Although the area of mental health and psychological well-being broadly defined has been central to the development of gerontology, our understanding of how ethnic and minority elderly fare in this area remains limited because of the absence of systematic data. The literature has predicted disadvantages among ethnic and minority elderly because of greater difficulties adjusting during old age given their disadvantaged situation in the larger society. Yet the evidence does not consistently support this prediction. Because most research is based on subjective

evaluations of psychological well-being that are made with important reference groups in mind, inequalities in objective conditions do not always translate into inequalities in subjective assessments (*see* Mental Health; Psychological Well-Being).

Even when research has focused on relatively more objective measures of psychological well-being, such as measures of depressive symptomatology, no clear-cut differences have been observed between African Americans and Whites at any age. The same is the case with respect to Mexican Americans, except that older Mexican American women appear to have relatively high rates of depressive symptomatology. In addition, there is some evidence of lower depressive symptomatology among the foreign-born, which supports the 'healthy migrant' effect also observed with regard to physical health. At the same time, recent older immigrants (within 10 years) appear to fare worse than people immigrating earlier in life. This is especially the case among women (*see* Depression).

There is also inconclusive evidence with regard to the mental health and well-being of the elderly from the various Asian Pacific Islander groups. Although some evidence suggests greater problems among recent immigrants, other evidence suggests that older immigrants experience more problems with the passage of time because of increasing isolation from the larger society as well as the increasing acculturation of the children. Children appear to fare better with the passage of time as they become assimilated and acculturated into the host society.

Systematic assessments of the mental health of American Indian elderly are also lacking, although there is an indication of high rates of depression among older women that is related to personal losses, social isolation, and acculturative stress. Kunitz and Levy found no differences in the prevalence of depression between elderly Navajo and the general population. They did find, however, that persistent depression was more prevalent among Navajo elderly women, although they acknowledged difficulties in assessing depression among men because it may be obscured by alcohol use, an observation also relevant with respect to the general population.

One area in which racial and ethnic differences in mental health status have been identified is cognitive impairment. African American and Hispanic elders have been identified as having higher rates of cognitive impairment than non-Hispanic Whites. The higher African American impairment, in particular, may be partly an outcome of their higher rates of small strokes, which is related to higher rates of cerebrovascular disease, which is associated in turn with higher rates of hypertension and diabetes.

Social Relationships

Conventional wisdom suggests that the elderly in ethnic minority populations are advantaged in their social relationships, particularly family and intergenerational relationships. African American, Hispanic, Asian American, and American Indian elderly all have been found to benefit from higher rates of coresidence with adult children and from social support from their extended families. Yet coresidence is often a matter of survival among these groups rather than simply a cultural preference. At the same time, lower coresidence among non-Hispanic Whites is evidence of their greater socioeconomic independence from their children. Research has shown over the years that although elderly in ethnic and minority populations have closer relationships with their children, they nevertheless report higher rates of unfulfilled expectations of filial responsibility than is the case among non-Hispanic White elderly, who appear more satisfied with what their children do for them. Clearly, availability of family members in the household or in close proximity is great support to ethnic and minority elderly who have few other resources, but it is not always a sign of an advantage in intergenerational relationships (*see* Social Networks, Support, and Integration).

Economic Status

Underlying much of the variation among the elderly from various ethnic origins is their great diversity in economic status. Clearly, relative to non-Hispanic White elderly, significantly higher proportions of African American elderly, most Hispanic elderly, and American Indian elderly live in poverty and have lower incomes. These differences reflect differences in educational background, occupational status, and past discrimination. Economic status differences are even greater with respect to wealth measured by net worth. One consequence of the economic condition of these groups is that they are disproportionately reliant on government programs for income, housing, transportation, and health care. Since African American and Hispanic elders rely disproportionately on Medicaid, Supplemental Security Income, public housing, and public transportation, they are particularly sensitive to changes in those programs.

Asian Pacific Islanders overall are more secure economically, although family incomes in these groups are spread over a larger number of family members than among non-Hispanic Whites. At the same time, given their greater proportion of foreign-born people, the economic status of Asian Pacific Islander elderly is negatively influenced by lower

Medicare coverage. Finally, much economic variation exists among the various Asian Pacific Islander groups that has not been adequately explored among the older population.

Conclusion

High rates of immigration from a variety of national origins are changing the complexion of the elderly population in the United States and other Western societies. This trend in the United States is being driven especially by Hispanic and Asian immigration, although there are pockets of immigrants from the former Soviet Union that bring a different ethnic mix as well. This immigration contributes to both disparities and diversity within the older population. While disparities are considered unjust and are the targets of programs to eliminate disparities, diversity in cultures, values, and beliefs can enrich a society. The challenge for scholars and policy makers is to protect diversity while reducing disparities. For this to occur, we need to improve our conceptual models for each separately and in tandem.

Examination of racial and ethnic differences in health suggests wide, continuing disadvantages for African American elderly but not for Hispanic elderly, at least with respect to mortality. American Indians have also narrowed the mortality gap, but little is known about their morbidity and functional health status. The mortality situation of most Asian Pacific Islander elderly appears to be favorable and may very well reflect a healthy immigrant effect also thought to benefit Hispanics.

Much less is known about mental health and psychological differences between groups because of a scarcity of data, especially on more objective indicators. With respect to social relationships, ethnic and minority elderly appear to be advantaged because of higher coresidence rates and greater contact with adult children; this coresidence and contact often signify a lack of options relative to non-Hispanic White elderly.

There is no question regarding the lower economic status of African American, most Hispanic, and American Indian elderly. Low incomes are compounded by even lower levels of net worth, which can be so important to the economic security of the elderly. Since these lower incomes contribute to worse health outcomes, especially for African Americans and American Indians, improving the socioeconomic status of minority groups would have a broad impact on improving the health and quality of life of minority elders. But the data suggest that disparities will remain even if incomes are equalized, which leads to the need for additional efforts to reduce racial segregation and social exclusion in the society.

Although the importance of understanding within-group diversity has been emphasized, especially among Asian Pacific Islanders and American Indians, national surveys that include adequate numbers representing the various subpopulations are impractical because of cost considerations. Although large studies of the elderly in the largest of these groups are possible and needed, smaller and more intensive ethnographic studies of the smaller groups will go a long way toward developing an understanding of the characteristics and needs of the elderly.

Finally, research on ethnic and minority elderly needs to give greater attention to the immigrant experience and how it influences the elderly, both positively and negatively. Elderly immigrants from a variety of ethnic and cultural backgrounds face a number of similar experiences that have not been adequately understood or incorporated into our conceptual frameworks.

See also: Alcohol and Drugs; Cancer and Age; Cardiovascular System; Depression; Disability, Functional Status and Activities of Daily Living; Epidemiology; Mental Health; Psychological Well-Being; Social Networks, Support, and Integration.

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Evolution and Comparative Biology

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Glossary

Allele – A variant form of a gene.

Antagonistic Pleiotropy – Occurs when multiple effects of a genetic change are opposed in their impact on fitness.

Drosophila – A fly genus commonly used in laboratory research.

Fitness – Net reproductive rate of an organism, weighted according to the growth of the population as a whole.

Fitness Component – A character that numerically defines fitness, e.g., fecundity at a particular age.

Germline – The cells in an individual that become gametes or offspring.

Late Life – A distinct phase of life that happens at ages after aging ceases.

Malthusian Parameter – The asymptotic growth rate of a population growing without any ecological limitation. Often equal to fitness.

Mutation Accumulation – The increase in frequency of deleterious mutations at later ages due to the weak force of natural selection at those ages.

Soma – The part of the organism that does not produce offspring directly, i.e., that is not germline tissue.

Introduction

Aging and late life, like all other biological characteristics, evolve. However, the evolutionary mechanisms underlying aging and late life are different from those underlying all other prominent features of organisms. Aging and late life evolve through the dereliction of natural selection at later ages, so that normal categories of biological thought, such as 'function,' 'adaptation,' and 'purpose,' cannot be relied on in the study of aging and late life. This idea forms the basis of the evolutionary theory of aging and late life, with which this article begins. Experimental tests of this theory are then discussed. Finally, the comparative biology of aging and late life is reviewed.

Evolutionary Theory of Aging and Late Life

Definition of Aging

From the perspective of evolutionary biology, the most important feature of the organism is its fitness: net reproductive output, measured from one generation to the next. This variable is usually very hard to measure. Instead, evolutionary biologists commonly study components of fitness, such as viability and

fertility. The characters of interest to an evolutionary biologist studying aging are the age-specific components of fitness: age-specific survival probability and age-specific fecundity. The definition of aging that is normally used in evolutionary biology is a persistent decline in age-specific fitness components, both survival and fertility characters, as a function of age, in which this decline is not due to any external factor, such as deteriorating environment, pathogens, and so on.

Definition of Late Life

Late life is a post-aging period of life that is characterized by the cessation of aging. From an evolutionary perspective, late life is a distinct phase of life, like aging, and the characters of interest are also the age-specific components of fitness: age-specific survival probability and age-specific fecundity. However, the major difference between late life and aging is that there is no longer a decline in these age-specific fitness components in late life. That is, age-specific survival and fecundity stop declining and 'plateau.' The onset of late life can be defined as the age at which age-specific fitness components stop deteriorating, on average.

Evolutionary Theories of Aging

Evolutionary discussions of aging date back to A. R. Wallace and A. Weismann in the nineteenth century. Since these authors were writing before the advent of theoretical population genetics, the core of modern evolutionary theory, their ideas are often incoherent or opaque.

One of the major errors made at that time was the proposal that aging evolved to eliminate elderly individuals to make way for the young. This is an idea that is still cited today, at least by authors without training in evolutionary biology. The key mistake in this proposal is that it presumes that, without aging, there would be an abundance of elderly, infirm organisms in natural populations. For the vast majority of species in natural populations, however, this is not likely to be the case, because disease, predation, accident, and bad weather normally remove individuals before significant aging has occurred. Therefore, physiological mechanisms of aging do not usually remove older individuals from the population.

By the middle of the twentieth century, R.A Fisher, J. B. S. Haldane, P. B. Medawar, and G. C. Williams had developed a different kind of evolutionary theory of aging. Their proposals were based on the idea that natural selection should operate with less effectiveness on later fitness components because these characters would be expressed less often, per lifetime, than early fitness components, simply because the probability of survival from birth to any age falls with age. In 1941, Haldane proposed that the human genetic syndrome of Huntington's disease was common relative to many other genetic diseases, despite its lethality, because it was not expressed until middle age, after most of its carriers would have reproduced. Verbal hypotheses like these set the stage for the development of the formal evolutionary theory of aging, which was to follow in the last third of the twentieth century.

The mathematical population genetics of aging were developed primarily by W. D. Hamilton and B. Charlesworth in publications that appeared from 1966 to 1980. In this formal analysis, it was shown that Darwinian fitness is often given by the Malthusian parameter associated with a particular genotype. Given the particular age-specific fitness components for a genotype, its Malthusian parameter is given by r in the following equation:

$$\sum e^{-rx} l(x) m(x) = 1 \qquad [1]$$

where the sigma indicates summation proceeding over all positive values of x; x indicates age; $l(x)$ is the probability of survival from birth to age x; $m(x)$ is fecundity at age x; and e is the natural exponential. Effectively, the Malthusian parameter is a sort of averaged net fecundity over the life span, allowing for losses due to mortality and the effects of parallel growth in the entire population.

The mathematical analysis of Hamilton and Charlesworth went on to calculate the impact on fitness, determined by the Malthusian parameter, of age-specific changes in fitness components. They found that, when there is a proportionally uniform change in an age-specific survival probability, such as a 10% reduction, the impact on fitness was differentially scaled as a function of age according to the expression

$$s(a) = \sum_{x=a+1} e^{-rx} l(x) m(x) \qquad [2]$$

where a is the age at which survival probability is changed. Age $a+1$ is the age at which the summation starts. Note that after the last age at which offspring are produced in the population, $s(a)$ is zero forever after, and before the first age at which offspring are produced, $s(a)$ is always exactly one. Between the first and last ages of reproduction, $s(a)$ progressively falls (**Figure 1**). This result shows that the force of natural selection acting on survival falls

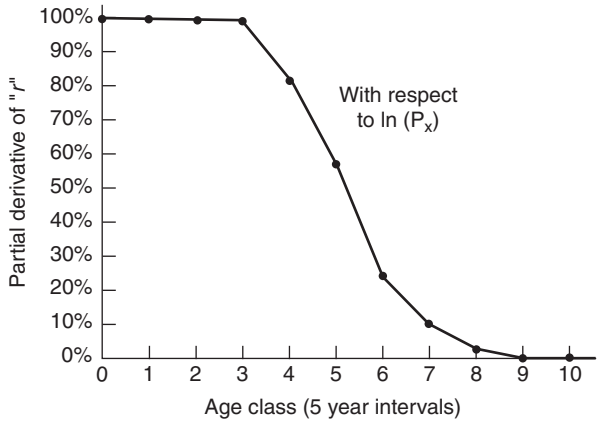

Figure 1 The force of natural selection, calculated in terms of the impact on fitness (*r)* of a proportionally uniform change in age-specific survival probability [*P*(*x*)]. This curve might characterize a species that started reproduction after 20 years of age. The curve plotted shows the force of natural selection relative to its impact before the onset of reproduction, neglecting any absolute scaling effects related to generation time. Qualitatively similar results will arise for any sexually reproducing species, though the width of the initial plateau, the rapidity of the subsequent decline, and the point at which zero is reached will vary.

with adult age, at least when the assumptions of this analysis are met.

A similar analysis for effects on age-specific fecundity gives a comparable 'scaling equation,' as follows:

$$s'(a) = e^{-ra}l(a) \qquad [3]$$

In this case, if population growth is not negative, then the force of natural selection once again declines with age. But if population growth is strongly negative, then the force of natural selection may indeed increase with age for a time. This corresponds to a situation in which a population is declining rapidly toward extinction, so that two offspring produced when the population size is 600 are 'worth' less to natural selection than two offspring produced some time later when the population size is 60. In the latter instance, the offspring are a larger proportion of the population. However, these cases normally are rare, since populations declining rapidly to extinction will often become extinct, rendering them unobservable. The typical pattern remains one in which the force of natural selection acting on fecundity declines with age.

From these results, population geneticists have been able to explain the evolution of declining age-specific fitness components, or aging. These results are very general, among demographies, and have no physiological content. In particular, they do not require or predict the action of any particular mechanism of physiological deterioration. The evolutionary theory of aging accounts for aging in terms of a pervasive failure of adaptation, the particulars of which must be as idiosyncratic to species as the particulars of adaptation for those species are. For this reason, evolutionary biologists have generally been extremely skeptical of proposals that attribute 'the cause of aging' to any specific physiological mechanism.

Evolutionary Theory of Late Life

The first observations of a late life phase came from human age-specific mortality rate data. It had been noted for years that late life mortality rates did not conform to normal aging patterns. That is, age-specific mortality rates stopped increasing exponentially at late ages and stabilized at some rate below 100%. It was not until 1992 that J. R. Carey and colleagues demonstrated this 'plateauing' in late life age-specific mortality rates in several large cohorts of medflies that late life first began to be accepted as a phase of life distinct from aging.

The same mathematical evolutionary theory described previously was expanded by L. D. Mueller and M. R. Rose to include late life. Recall that this theory is based on the declining age-specific force of natural selection on survival probabilities. According to this theory, survival probabilities should decline during the first part of adulthood, or in terms of mortality rates, age-specific mortality rates should exponentially increase. This occurs because the force of natural selection acting on survival is rapidly declining during those ages. However, after the last age at which offspring are produced, $s(a)$, or the force of natural selection acting on survival, is 0 for all remaining ages. Mueller and Rose predicted that age-specific mortality rates should mimic the plateau in the force of natural selection at late ages and also plateau because the force of natural selection is no longer able to distinguish fitness differences in survival at different ages within late life.

As with the force of natural selection acting on survival probabilities, C. L. Rauser and colleagues noted that the force of natural selection acting on fecundity, as described previously, asymptotically declines to zero at late ages. The age at which $s'(a)$ declines to zero is dependent on the last age of survival in the environment in which evolution has occurred, rather than the last age of reproduction, as with survival. Therefore, age-specific fecundity should stop declining and plateau at late ages, similar to the plateau in age-specific mortality rates, because the force of natural selection acting on fecundity is so low at late ages that it cannot distinguish fitness differences in fecundity.

The expansion of the evolutionary theory of aging to include late life has been paramount in the understanding of both aging and late life. Although a more formal mathematical derivation of the late life theory is necessary, this theory, as it has already been interpreted, readily allows for testable predictions regarding age-specific fitness components of late life. Now evolutionary biologists must be concerned with not only why aging happens, but also why aging ceases at late ages.

Population Genetic Hypotheses of Aging and Late Life

Subordinate to the general evolutionary theories of aging and late life are alternative population genetic hypotheses for the evolution of aging and late life. These hypotheses presume the validity of the evolutionary theories, particularly that the force of natural selection declines with adult age until late ages, when it approaches zero. These hypotheses are not incompatible with one another; they could be simultaneously valid. There are two population genetic mechanisms of primary interest, although others have been proposed. They are antagonistic pleiotropy and mutation accumulation.

Antagonistic Pleiotropy Antagonistic pleiotropy arises when alleles that have beneficial effects on one set of fitness components also have deleterious effects on other fitness components. Both Medawar and Williams argued for the importance of this population-genetic mechanism in the evolution of aging during the 1950s. The underlying concept is one of trade-off: alleles with beneficial effects must in some way 'pay' for those benefits with bad side effects.

Charlesworth and Rose analyzed the action of antagonistic pleiotropy mathematically with regards to aging. They showed that the declining force of natural selection would lead to a tendency for selection to fix alleles that have early beneficial effects, but later deleterious effects. This biases evolution toward the production of vigorous young organisms and decrepit old organisms. In addition, antagonistic pleiotropy may lead to the maintenance of genetic variability for aging and related characters, which is of great experimental significance. At the theoretical level, antagonistic pleiotropy is an important possible mechanism for the evolution of aging. However, the empirical work does not show that it always arises.

Mueller and Rose quantitatively demonstrated that the slowing of age-specific mortality rates in late life can arise from antagonistic pleiotropy in numerical simulations. As yet, there is no comprehensive analytical theory for the role of antagonistic pleiotropy in the evolution of late life.

Mutation Accumulation The other cogent population genetic mechanism for the evolution of aging and late life is mutation accumulation. Mutation accumulation arises when the force of natural selection has declined to a point at which it has little impact on recurrent deleterious mutations with effects confined to late life. Medawar was the main advocate of the importance of this mechanism in the evolution of aging. Charlesworth analyzed mutation accumulation mathematically, showing that the frequency of deleterious mutations would rise with adult age because of the declining force of natural selection at late ages. This population genetic mechanism also tends to maintain genetic variability for aging, like antagonistic pleiotropy.

Mueller, Rose, and Charlesworth all addressed the role of mutation accumulation in late life and demonstrated that it can generate mortality rate plateaus. This theory is more complete than the corresponding theory of antagonistic pleiotropy.

Experimental Studies of the Evolution of Aging and Late Life

Laboratory Evolution of Aging

Development and Design of the Experimental Approach Unlike many areas of biology, the evolutionary theory of aging provides a strong, mathematically developed base on which to plan experiments. One of the most elegant experimental approaches in gerontology is the manipulation of the force of natural selection to shape the evolution of aging patterns. This experimental strategy was first proposed by E. B. Edney and R. W. Gill in 1968. Some preliminary experiments of this kind were performed in the 1960s and 1970s by J. M. Wattiaux, R. R. Sokal, and Rose. Properly replicated experiments were not performed until the 1980s, particularly by Rose, L. S. Luckinbill, and R. W. Arking. These experiments are now routine in evolutionary gerontology, almost always using fruit fly species of the genus *Drosophila*.

The design of these experiments depends on the manipulation of the age of reproduction. When the timing of reproduction is maintained for a number of generations, the force of natural selection will be focused at that age. For example, normal fruit fly culture involves reproduction at 14 days of age, when cultured at 25°C, with just a few hours for egg laying allowed. This focuses the force of natural selection on that relatively early age. Genetic effects expressed

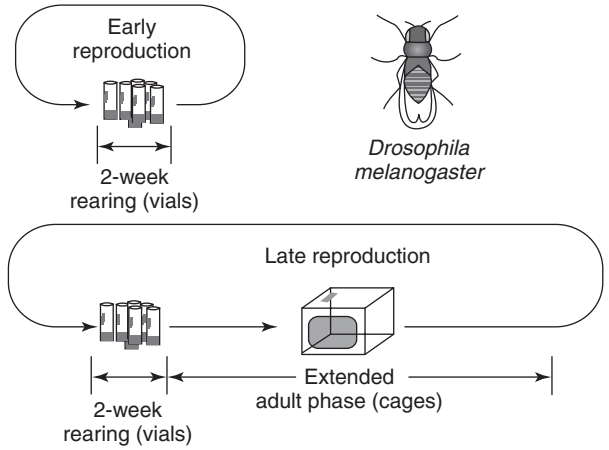

Figure 2 Method of selecting on fruit fly cultures for different times of reproduction. The early reproduced flies are reared in vials as a cohort, emerging at about 10 days when reared at 25°C. After a few days for mating among the adults, females are allowed to lay eggs in new vials at 14 days of age. These eggs are laid over just a few hours and the adult flies are then discarded, allowing the eggs to start the next generation as a synchronized cohort once more. Late-reproduced flies are reared in vials as a cohort, like early reproduced flies, until 14 days of age. The adults are then transferred into large Plexiglas cages, where they are kept as an aging cohort, without replacement, for an additional period of time. During this time, all eggs are discarded shortly after they are laid. After a prolonged adult period, the surviving females from a cage are given the opportunity to lay eggs over 1 or 2 days. These eggs are then used to start the next generation as a synchronized cohort.

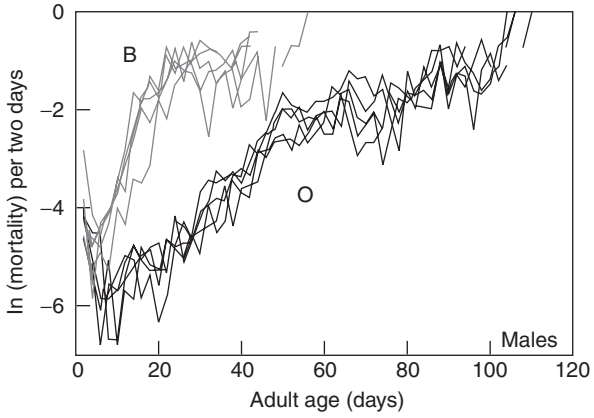

Figure 3 The mortality results obtained with different regimes of culture maintenance are shown for male populations of *Drosophila melanogaster*. Early reproduced (B) populations have lower mean and maximum longevities, compared with late reproduced (O) populations. The early reproduced (B) populations also have an earlier age at which mortality rates stop increasing and plateau, compared with the late reproduced (O) populations. About 20 years of selection had been imposed on the different populations prior to these assays. Both groups of populations descended from a common ancestor and were replicated fivefold. Data are from Rose MR, Drapeau MD, Yazdi PG, Shah KH, Moise DB, Thakar RR, Rauser CL, and Mueller LD (2002) Evolution of late-life mortality in *Drosophila melanogaster*. *Evolution* 56: 1982–1991.

at later ages, much after 14 days, are subject to negligible natural selection. This type of experimental regime allows the evolution of relatively early aging.

An alternative experimental regime is to keep adult flies alive for some time before they are allowed to contribute offspring to the next generation. This is done by discarding any eggs that they lay until they have reached the age allowed for reproduction, which can be as late as 10 weeks from emergence of the larva. Note that this procedure does not require that the fruit flies be kept virgin; mating is allowed, just not successful reproduction. This regime allows for the evolution of relatively late aging. The contrast between this procedure and that used with early reproduction is shown in **Figure 2**.

Effects of Changing the Force of Natural Selection The results of changing the age at which selection is strong have been striking for aging. **Figure 3** shows typical data for fruit flies. Mean and maximum life span dramatically increase when the force of natural selection is experimentally strengthened at later ages, as the evolutionary theory predicts. In addition, female fecundity, male virility, flight endurance, locomotion, stress resistance, and so on are also enhanced. This is an extremely important result for our understanding of aging. It reveals that aging is not a by-product, accidental or otherwise, of an unmodifiable biochemical process. Rather, aging is an easily modified product of evolution.

Experimental Population Genetics of Aging

Given the preeminence of natural selection in determining patterns of aging, the next major experimental question is the population genetic mechanisms that underlie the evolution of aging. As outlined previously, there are two main hypotheses, antagonistic pleiotropy and mutation accumulation. The evidence that has been brought to bear on these hypotheses has been of two main kinds: (1) correlation between relatives and (2) indirect responses to selection. In addition to the choice between these hypotheses, there is the issue of the number of genetic loci involved in the evolution of aging. A number of different methods have been used to address this question.

Correlation between Relatives One of the classic techniques in population genetics is the study of the correlations between relatives for characters that are, in part, inherited. This technique can also be used to study the degree to which two or more characters tend to be inherited together. When they are, this usually indicates some degree of pleiotropy among

the alleles affecting these characters. In particular, correlated inheritance is indicative of the pattern of pleiotropy, with positive correlations indicating that alleles affect two characters in the same direction, and negative correlations indicating that alleles affect two characters in opposite directions, on average.

The antagonistic pleiotropy mechanism for the evolution of aging requires that some early and late characters exhibit negative genetic correlations with respect to each other. This pattern has been found in a few cases, notably between early fecundity and longevity in fruit flies. However, a positive correlation has been found in many more. Artifacts may be responsible for some of these latter results, particularly inbreeding and novel environment effects, both of which bias genetic correlations toward positive values.

Mutation accumulation requires that genetic correlations between early and late characters be approximately zero. The problem for this hypothesis is that these genetic correlations tend to be strongly positive among newly occurring mutations or intermittently negative in long-established genetic variation. Mutation accumulation also requires that heritable genetic variation increases with age. This result has been found in some fruit fly experiments, but not in others.

Both antagonistic pleiotropy and mutation accumulation mechanisms receive weak and inconsistent experimental support from genetic correlations. An important factor, however, is that they may act simultaneously and, in so doing, cancel out the predicted effects of both mechanisms on correlations between relatives.

Indirect Responses to Selection To some extent, selection experiments are better able to detect the simultaneous action of antagonistic pleiotropy and mutation accumulation. When, for example, postponed aging has evolved as a result of later reproduction in fruit flies, it is often observed that antagonistic pleiotropy causes an immediate reduction in early fecundity. With antagonistic pleiotropy, it is expected that some early, functional characters will be depressed by the laboratory evolution of postponed aging. The observation of this pattern in a number of instances, together with evidence obtained from correlations between relatives, indicates that antagonistic pleiotropy is, in some cases, an important mechanism in the evolution of aging.

The effects of mutation accumulation can also be observed in laboratory evolution experiments. For example, when later reproductive opportunities are denied, it is expected that after many generations later fecundity should be reduced, due to the accumulation of alleles with late-acting deleterious effects. This result was obtained by Mueller in fruit flies denied later reproduction for more than 100 generations. Other such long-term deteriorations have been obtained by Rose and colleagues for other characters, especially stress resistance. Mutation accumulation evidently can act over hundreds of generations to undermine functional characters when the force of selection is reduced, making it an important mechanism for the evolution of aging.

The Number of Genes Affecting Aging Earlier evolutionary theorists, such as Williams and J. Maynard Smith, argued that an extremely large number of loci are likely to affect aging. This idea gave rise to some pessimism among evolutionary biologists concerning the feasibility of postponing aging. The success of laboratory evolution experiments in producing organisms with genetically postponed aging, however, forced a reexamination of earlier assumptions.

Luckinbill and colleagues as well as E. W. Hutchinson, J. E. Fleming, S. D. Pletcher and colleagues, and Rose examined the number of alleles affecting aging in fruit flies using a variety of experimental techniques. Only effective factor estimation suggested that the number of loci is small, but the result probably arose from arithmetical artifacts. Other estimates have given values in the hundreds of loci for *Drosophila*. At present, the best answer to the question of the number of genes controlling aging is 'many.'

Experimentally Testing the Evolutionary Theory of Late Life

Since the definitive discovery of late life in 1992 and the theoretical analysis of the evolution of late life by Mueller and Rose in 1996, experimental studies have tested predictions of the evolutionary theory of late life. Both mortality rate and fecundity patterns in late life have been measured using populations of fruit flies with different ages at which the force of natural selection declines to zero, as described earlier. Thus far, all such experimental studies have strongly corroborated the predictions inferred from evolutionary theory.

Effects of Changing the Force of Natural Selection The effects of changing the age at which the force of natural selection is strong have been striking for both aging and late life. The evolutionary theory of late life predicts that changes in the last age of reproduction should correspond to changes in the age that mortality rates stop increasing and plateau. **Figure 3** shows the data from one such pairwise comparison. Rose and colleagues showed that the age at which mortality rates stabilize (i.e., the start of

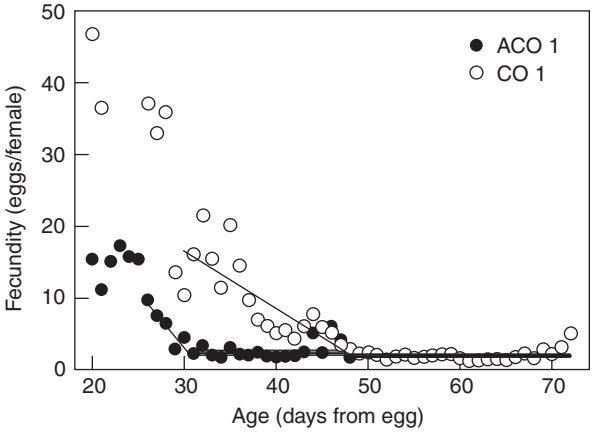

Figure 4 The fecundity results obtained with different regimes of culture maintenance are shown for female populations of *Drosophila melanogaster*. The early reproduced (ACO) population and later reproduced (CO) population both demonstrate a decline in fecundity followed by a plateau in population fecundity at late ages. In addition, the early reproduced (ACO) population has an earlier age at which fecundity stops declining and plateaus, compared to the later reproduced (CO) population. The results presented here are similar for five independent comparisons between populations cultured for early or later reproduction (data not shown). Data are from Rauser CL, Tierney JJ, Gunion SM, Covarrubias GM, Mueller LD, and Rose MR Evolution of late-life fecundity in *Drosophila melanogaster*. *Journal of Evolutionary Biology*. In press.

late life) is later in populations in which the force of natural selection is experimentally strengthened at later ages.

The evolutionary theory of late life also predicts similar results for fecundity probabilities. That is, fecundity should stop declining and plateau at late ages before it declines to zero, and the plateau in fecundity should correspond to changes in the last age of survival in the population's evolutionary history. Recall that the last age of survival is just after the last age of reproduction in the populations of fruit flies described previously because of the way in which these populations are maintained. Rauser and colleagues have shown that populations having different ages at which the force of natural selection acting on fecundity collapses have corresponding transitions to late life fecundity plateaus (**Figure 4**).

Population Genetic Mechanisms in Late Life Both theoretical and experimental analyses have revealed that late life patterns are greatly affected by natural selection. The next question is whether the population genetic mechanisms that underlie the evolution of aging also underlie the evolution of late life.

With antagonistic pleiotropy, genes having a positive effect on early age fitness components also have a detrimental effect at later ages. Therefore, with antagonistic pleiotropy involving late life, a shift to an earlier age of reproduction should result in a rapid shift in the age at which fitness components stabilize at late ages. Rose and colleagues and Rauser and colleagues demonstrated such rapid shifts in the onset of late life in mortality and fecundity, respectively, in *Drosophila*. These experiments also incidentally provide support for the evolutionary theory based on the force of natural selection because the ages at which the force of natural selection decline to zero, or the start of late life, evolutionarily shift with the age of reproduction.

With mutation accumulation, mutations that affect later ages are expected to accumulate within a population. It is also assumed that most of these mutations will have a recessive effect on the specific age class that they affect. Therefore, the effects of mutation accumulation can be observed in late life if crosses between populations that have been maintained at exactly the same age of reproduction, independently, show differences in late life patterns compared to the populations from which these crosses originated. However, Rose and colleagues did not observe such differences in late life survival probabilities after performing all possible crosses for five genetically divergent populations. Although their experiment did not support mutation accumulation as a genetic mechanism in the evolution of late life, it did not necessarily refute it. Consequently, the jury is still out regarding the involvement of mutation accumulation in the evolution of late life.

Comparative Biology of Aging and Late Life

Presence and Absence of Aging

Comparative Predictions of the Evolutionary Theory of Aging The evolutionary theory of aging is unusual among theories of biology in that it makes some absolute predictions. The experimental corroborations of the prediction that the pattern of aging should evolutionarily respond to manipulation of the force of natural selection have already been mentioned. With even greater strength, the evolutionary theory of aging predicts that all species that exhibit a well-defined separation of germline from soma must age. Conversely, the evolutionary theory predicts that all species with strictly symmetrical fissile (splitting in two) reproduction must be free of aging. (This does not imply absolute immortality, since such organisms could still die from disease, predation, or mechanical injury.) These two predictions can be tested extensively using comparative data.

However, many species exhibit neither a well-defined soma nor fissile reproduction. Colonial

coelenterates, such as corals, or grasses may have fairly ambiguous delineation of 'organisms.' Still other forms may combine fissile with sexual reproduction. In these cases, the evolutionary theory does not provide any simple prediction about the pattern of aging. Fully developed population genetics theory could, of course, be formulated to address any of these 'hybrid' cases, and some progress along these lines has been made by M. E. Orive. There is no fundamental violation of theory, only some difficult special cases.

Aging in Sexual Metazoa There are very large taxonomic groups in which aging is predicted to be universal. The most common type is probably the metazoa that reproduce only sexually and lack any sort of vegetative 'spreading' such as that exhibited by corals. In such forms, the life of each organism begins from an egg that develops into an immature animal and ultimately into a sexually mature animal. Sometimes a derivative asexual, typically parthenogenetic, form evolves from such a sexual species, but the essential life cycle is maintained, with nothing approaching fissile reproduction. Among other prominent examples, both the insects and the vertebrates exhibit this type of life cycle.

Insects and vertebrates are two of the most intensively studied groups of species. There are hundreds of thousands of insect species, many of which have been studied because of their economic importance. There are far fewer vertebrate species, but they have been studied with even greater zeal than the insects. Often actuarial or physiological aging is not detected in wild populations of these organisms. For example, several fish species have been studied in which some individuals sampled from the wild appear to have attained great age without signs of physiological aging, notably sturgeon, ocean perch, and rockfish. However, no cohort of fish maintained in the laboratory free of contagious disease until death has failed to detect aging. For mammals, the evidence for the ubiquity of aging is strongest with respect to both the numbers of species studied and the quality of their care. Among all of these organisms, over the many studies that have been conducted, none have been shown to lack aging. There are no reputable refutations of the prediction of the evolutionary theory of aging that all these species must age.

Aging in Strictly Fissile Forms At the other end of the evolutionary spectrum with respect to aging are the fissile species. It is important to understand that the concept of fissile here does not mean merely asexual reproduction or budding. It is now well known that budding yeast exhibit aging, as does the asexual protozoan *Tokophyra*. When asexual reproduction is sufficiently asymmetrical, there may be a pseudo 'adult' producing 'juvenile' offspring. When this occurs in a way that can give rise to differential evolution of such adults and juveniles, then aging can evolve. The cases in which aging cannot evolve, according to the theory, are those with strict symmetry between the products of fission, as in the fissile yeast *Saccharomyces pombe* and free-floating bacteria. In these cases, if aging were to occur, it would extinguish all the descendant lineages, wiping out any such aging lineage, because senescent deterioration would then deteriorate from cell division to cell division. This outcome would be opposed by natural selection acting with full force, which would thus halt such aging among surviving lineages. As required by theory, all such cases of strictly symmetrical fission do not apparently exhibit aging. Once again, however, this does not guarantee immortality; it is not a refutation of the evolutionary theory of aging to show that a particular bacterium eventually dies.

Correlated Evolution of Aging and Other Characters

Quantitative Patterns of Aging One of the most fertile seedbeds for gerontological speculation over the last century or more has been patterns of aging among species that exhibit it. For example, it is usually found that birds live longer in captivity than mammals of a similar size, and this has provoked speculation about relationships between the physiology of flight and that of aging. It is also known that larger mammals tend to live longer than smaller mammals. Longer-lived, larger mammals also tend to have lower fecundity, per brood or per year. Finally, in the 1950s, G. A. Sacher claimed that more cephalized (larger brain weight relative to body weight) mammals tended to live longer. This again led to speculation about the physiological advantages of large brains.

With respect to these patterns, the evolutionary theory of aging makes no absolute predictions. Varied evolutionary mechanisms could generate patterns of this kind. Thus, any particular pattern of aging among aging species does not constitute any kind of test of the evolutionary theory of aging. However, this theory may be helpful in interpreting such findings.

Artifacts in Comparative Biology While it might be supposed that evolutionary biologists must be strong advocates of the use of between-species comparisons, in fact, evolutionary biologists have developed a number of profound criticisms of the comparative

method. One is that the statistical degrees of freedom can be greatly overestimated in comparative studies. If one studies 80 species of insects compared with 60 species of mammals, a naive analysis of the data would yield striking correlations between life span, type of skeleton, and number of limbs, given the more than 135 degrees of freedom. But in fact there are no degrees of freedom in this study, because there are only two independent points of data, and no absolute hypotheses with which to compare them. Fortunately, evolutionary biologists have developed methods for correctly calculating the statistical power of any particular comparative analysis. Unfortunately, the corrected values for degrees of freedom are often much less than the initial assumptions.

A second major problem with many comparative analyses is that they are confounded with spurious variables that are already known to have an effect on the characters of interest. The most common of these is body weight, which in mammals, for example, usually increases with (1) the size of most bones, (2) brain size, (3) longevity, (4) brood interval, and so on. If a biological variable that also positively depends on body size is studied for its bivariate correlation with longevity, it may be found to correlate positively with longevity, all other things being equal. However, with enough effort, this problem can be largely obviated using multivariate statistical methods.

Third, comparative correlations between characters can be generated by both (1) pleiotropic effects of genetic variants evolving in response to an unknown selection mechanism and (2) ecologically correlated selection mechanisms acting on genetically independent characters. Determining which of these two has been involved in the comparative patterns of aging in a particular taxon will be difficult. For example, it has been suggested that the greater longevity of large mammals is due to an unknown physiological advantage of larger size. It has also been suggested by Charlesworth that the greater longevity of large mammals arises because they have lower mortality rates in nature, which is known to be common, thereby preserving a higher intensity of natural selection at later ages and the evolution of relatively delayed aging. Evaluating these two alternative hypotheses across some dozens of mammalian species is a daunting task.

All of these points together suggest that comparative patterns of aging are among the worst possible sources of inference concerning aging. It is easy to obtain findings that are entirely artifactual, while it is difficult to distinguish between competing hypotheses.

Comparative Natural History of Aging It is difficult to maintain that there is much if any profundity about comparative patterns of aging, leaving aside the issue of the presence or absence of aging. In well-studied groups, like the mammals, it is generally the case that most species array themselves along a continuum stretching from small, fecund, short-lived organisms, such as mice, to large, low-fecundity, long-lived organisms, such as elephants. Within this overall spectrum there are deviations, most dramatically the bats, which on average live much longer than comparable terrestrial mammals. This is an illustration of the general pattern that flightless species age faster than those with flight, even within groups like birds or mammals. It is also the case that species equipped with poison or armor frequently live longer in captivity than comparable species without these adaptations.

The explanation that the evolutionary theory of aging can offer for these patterns is that taxa that have mortality reduction because of a characteristic adaptation, like flight in most birds, may thereby, for purely mathematical reasons derivable from Eq. [2], have an increased force of natural selection at later ages. This increased force would then lead to the evolution of relatively slower aging, all other things being equal. Such mortality reduction can also arise from poison fangs in snakes, armor in turtles, or great body size in elephants. Moreover, this evolutionary effect could have nothing to do with any immediate physiological benefit arising from poison, bulk, or wings.

Cessation of Aging in Late Life

The cessation of aging at late ages has been found in a number of organisms, including fruit flies, medflies, beetles, wasps, nematodes, yeast, and humans. These organisms also all undergo normal aging. Although the discovery of late life is relatively recent, it seems to be common among aging organisms.

See also: Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates; Theories of Aging: Biological.

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Exercise and Physical Activity

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Glossary

Exercise – Planned, structured, and purposeful training designed to improve fitness.

Flexibility – Range of motion for a joint or multiple joints.

Physical Activity – Any bodily movement produced by the muscles that results in increased energy expenditure.

Introduction

Increasing regular physical activity is becoming widely recognized as one of the most important strategies for improving and maintaining the health and well-being of older adults. There is an extensive body of literature documenting the health benefits of physical activity across diverse older populations as well as programs and strategies to promote physical activity in this population. Although increasing physical activity is a national health priority, the majority of older adults do not meet the current recommendations for physical activity. The purpose of this article is to provide a summary of what is known about physical activity and exercise among older adults. The sections that follow present current levels of physical activity among older adults, including their activity preferences, the role of exercise in chronic disease management, and the determinants of physical activity in the aged. Gaps in knowledge are identified along with recommendations for directions in research.

A variety of terms are used in reports describing the prevalence of physical activity, including general physical activity, leisure-time physical activity, exercise, and sedentary behavior. Physical activity, which is defined as any bodily movement produced by the muscles that results in increased energy expenditure, is the more inclusive term and covers a broad array of activities. Exercise is a subcategory of physical activity and is characterized as planned, structured, and purposeful training designed to improve fitness. Leisure-time physical activity, another subcategory of physical activity, is any type of physical activity engaged in during an individual's spare time and does not include occupational activity. Lifestyle activity (i.e., gardening, yard work, housework, climbing stairs, and parking further away) may contribute to health benefits when combined with other forms of moderate-intensity activities such that at least 30 min of moderate-intensity activity is accumulated. The most common forms of exercise reported for older adults are aerobic or endurance exercise and strength or resistance training. Less reported forms of exercise include balance and flexibility training.

Importance of Aerobic, Strength Training, Range of Motion, and Balance Exercises

The current recommended level of aerobic activity for adults age 60 and older is 30 min of moderate-intensity activity, such as brisk walking, on 5 or more days per week. Older adults are also encouraged to engage in resistance training on 2 or more days per week. However, to obtain optimal health benefits, it is important for older adults to engage in four types of exercise: endurance or aerobic exercise, strength training or resistance exercise, flexibility exercises, and balance exercise. Combining aerobic exercise with strength training, flexibility, and balance exercises ensures that all components of the musculoskeletal system are fit and will enhance physical functioning in

older adults. To ensure cardiovascular adaptations and changes in cardiovascular disease risk factors, older adults should include large-muscle, rhythmic aerobic exercises such as walking, running, swimming, or cycling in their exercise routine. Initiating and maintaining regular light to moderate aerobic exercise may reduce the rate at which physical functioning declines and improve the quality of life for older adults. More favorable health benefits from aerobic training occur when exercise is performed at the moderate to vigorous level. Few adverse events occur from exercising at this intensity; however, progression to this level should be gradual and dependent on the health status and initial fitness level of the individual. Older adults should also be encouraged to lead an active lifestyle, accumulating moderate-intensity activity through both lifestyle activities and moderate-intensity exercises.

Strength training on 2–3 days per week is essential for preserving muscular strength and physical functioning. Strength training should target all of the large muscle groups and should be of sufficient stimulus to improve strength but not cause injury. Strength training is necessary to slow the progression of sarcopenia, which is a decline in muscle mass that occurs with aging. Strength training is suggested to combat the weakness, frailty, and declines in physical functioning associated with sarcopenia. Numerous health benefits can be obtained from strength training, including the maintenance of or increased muscle mass in older adults and improved insulin action, bone mineral density, energy metabolism, and physical functioning. Strength training has also been demonstrated to reduce the symptoms of chronic illnesses such as heart disease, arthritis, and type 2 diabetes and to improve sleep. Furthermore, strength training may enhance an older adult's ability to engage in moderate-intensity aerobic exercise.

Flexibility is an often-overlooked yet essential component of exercise training for the older adult. Flexibility, which encompasses the range of motion of a joint or multiple joints, declines with aging due to structural changes in the tissues that affect function of the joint. Flexibility exercises can improve the properties of the muscle and/or connective tissue, reduce joint pain, and enhance muscle recruitment patterns. These physiological changes are associated with increased range of motion of the joints and improved mobility.

Balance exercises are also highly recommended for older adults due to the high incidence of falls within this population. Postural stability declines with age, and poor postural stability is associated with risk of falling. The optimal type and dose of balance exercises needed to reduce risk of falls and to improve postural stability are not yet clear. However, the research has shown that a broad-based exercise program that includes walking or dancing, strength training, flexibility, and weight transfer will enhance postural stability. Additionally, tai chi has been shown to enhance balance in older adults.

Prevalence of Physical Activity among Older Adults

Despite the multitude of health benefits associated with regular exercise, older adults tend to be the least active segment of the population. Combined data from the 1994 and 1996 Behavioral Risk Factor Surveillance System (BRFSS) survey indicated that more than one-third of adults aged 55–74 and 46% of adults over the age of 75 were inactive. The good news is that the prevalence of no leisure-time physical activity as assessed by the BRFSS is on the decline, particularly among older adults. Since 1989, the prevalence of physical inactivity has declined by 15 and 7% among men and women aged 50–59 years, respectively; 10 and 6% among men and women aged 60–69 years; and 10 and 12% among men and women 70 and older, respectively. However, whether this decline in the prevalence of physical inactivity translates into an increase in the prevalence of older individuals obtaining sufficient exercise to obtain health benefits is less clear. Data from the 2001 BRFSS indicated that 38% of men and 27% of women over the age of 75 were meeting the recommendations for moderate-intensity physical activity. These prevalence estimates are similar to those obtained from the 1990 National Health Interview Survey (NHIS), which found that 40% of men and nearly 26% of women over the age of 65 met the recommendations for physical activity. Furthermore, participation in aerobic activities is more common than strength training. Only 11% of those age 65 years and older report doing strength or resistance training 2 or more days per week.

Data have also been collected on walking patterns since 1987. Walking is the most common form of activity among persons of all ages and is the most frequently reported type of activity among older individuals who meet the recommendations for physical activity. From 1987 to 2000, there was a 3.5% increase in the percentage of men and a 4.8% increase in the percentage of women over the age of 65 who reported walking for physical activity. However, there was no increase in the percentage of individuals who met the recommendations for physical activity through walking within any age group.

Epidemiological evidence also suggests that certain subpopulations of the older population are less active

than others. Data from the combined 1994 and 1996 BRFSS indicated that the prevalence of physical inactivity was higher for African Americans than Caucasians. Nearly 50% of African Americans age 55 or older were inactive. Gender differences in the prevalence of physical inactivity were observed among Caucasians only. Caucasian women 65 and older had a higher prevalence of physical inactivity than men (31 and 36.3% for men and women 65–74 years of age, respectively; 37.1 and 47.4% for women and men 75 years of age and older, respectively). In general, people with higher body mass indexes (BMIs) or poorer perceived health are more inactive. Similarly, older adults with disabilities or chronic illnesses are less active than their healthy counterparts. Findings from the 2001 BRFSS survey found that 43.4% of adults aged 50 or older without any disabilities met the current Centers for Disease Control and Prevention/American College of Sports Medicine (CDC/ACSM) recommendations for physical activity and 17% were inactive. In contrast, among those aged 50 or older with a disability, only 28.8% met the recommendations for physical activity and nearly 36% were inactive. Likewise, among individuals age 65–74 with arthritis, only 26% met the recommendations for physical activity compared to nearly 32% of those without arthritis. Individuals 75 and older with arthritis were the least active segment of the population, with nearly 42% classified as inactive. The prevalence of physical activity or inactivity among older adults with other chronic illnesses is harder to delineate. There is little information in the literature about the national prevalence of physical activity among older adults with specific chronic illnesses such as cardiovascular disease, diabetes, or cancer. Likewise, there is little known about the prevalence of physical activity among older Hispanic, Asian, or American Indian adults.

Impact of Physical Activity on Health

Older adults can be faced with a variety of physical, mental, and emotional challenges and are often faced with life-changing circumstances. Hence, it is easy to understand why health-protective behaviors such as exercise may not be a priority within this age group. However, maintaining a regular exercise routine is essential for older adults. Aging is associated with several health conditions, including cardiovascular disease, diabetes, obesity, cancer, and arthritis. Key to improving both the primary and secondary prevention of these and other chronic illnesses and disabilities is regular participation in exercise.

There is strong and consistent epidemiological evidence demonstrating the relationship between regular participation and positive health outcomes. Early epidemiological studies often focused on the crude relationship between self-reported occupational and/or leisure-time physical activity and health outcomes such as cardiovascular disease. For example, transportation workers with sedentary jobs (e.g., drivers) had higher rates of heart disease compared to workers with less sedentary jobs (e.g., ticket takers). It has also been shown that there is a relationship between caloric expenditure from leisure-time physical activity and heart disease. Individuals who expended 2000 kcal/week had the lowest risk for heart disease. Other epidemiological studies focused on the relationship between cardiovascular fitness and health outcomes. Whether the studies looked at fitness or exercise patterns, epidemiological evidence indicates that regular participation in exercise is associated with lower rates of overall and cardiovascular mortality, cardiovascular disease, stroke, hypertension, non-insulin-dependent diabetes, dyslipidemia, and breast and colon cancers. There is also strong epidemiological evidence demonstrating that individuals who are sedentary are at higher risk for developing chronic illnesses. In fact, inactivity doubles the health risks and has a disease burden comparable to smoking.

While epidemiological studies have allowed for the detection of an association between exercise and fitness levels and health outcomes, they do not provide information on the optimal dose, type, or frequency of exercise required to achieve these health outcomes. This is why intervention research and training studies are important to fill the gaps. Intervention research allows investigators to manipulate the intensity, dose, and/or frequency of exercise to determine the minimal amount necessary to achieve health outcomes. Intervention research needs to be conducted at both the primary and secondary prevention levels. That is, interventions need to be conducted within relatively healthy but sedentary older adult populations and among older adults with chronic illnesses. Intervention outcomes in these populations should focus on not only health- or disease-related outcomes, but also on functional status (e.g., gait, balance, losses of function, independence), mental health status, cognitive functioning, quality of life, and prevention or delay of age-related declines.

To date, most intervention studies conducted with healthy older individuals have focused primarily on health- or disease-related outcomes, although in recent years many have begun focusing on functional outcomes. In healthy older adults, physical activity interventions have been able to increase activity levels, at least for the short term. These increases in physical activity have been associated with improvements in

fitness, flexibility, muscular strength, gait and balance, functional status, improved quality of life, improved blood pressure, and decreased risk of falls. Many have also demonstrated improvements in cardiovascular risk factors and psychological factors.

Intervention studies conducted among older individuals with chronic illnesses are less common. The majority of research on the benefits of exercise within the context of chronic illness has focused on heart disease, hypertension, peripheral vascular disease, arthritis, osteoporosis, and diabetes. A limited number of studies have been conducted among people with cancer, stroke, cognitive impairments, and disabilities. Some of the strongest evidence for the benefits of exercise comes from cardiac rehabilitation programs. Individuals with heart disease who participate in an exercise-based cardiac rehabilitation program have reduced all-cause and cardiac mortality, lower total cholesterol, triglyceride, and systolic blood pressure levels compared to individuals who attend non-exercise rehab programs. It is estimated that individuals who attend an exercise-based rehab program have a 20% reduction in all-cause mortality and a 25% reduction in cardiac-related mortality. A recent meta-analysis of exercise interventions in hypertensive individuals demonstrated that moderate-intensity aerobic exercise is associated with a 2% reduction in systolic blood pressure. Interventions focused on peripheral vascular disease have demonstrated increased functional capacity, determined by an increase in time to pain during walking, after participating in an aerobic exercise program. Likewise, aerobic exercise has been shown to increase insulin sensitivity among diabetics, resulting in improved management of diabetes. A large number of studies have been conducted among older people with arthritis, and both strength and aerobic exercise have been associated with improved physical functioning, including postural stability and gait, decreased pain, increased range of motion, increased muscular strength, decreased fatigue, and improved quality of life. Participation in weight-bearing exercise and strength-training interventions is known to help maintain bone mineral density among individuals with osteoporosis. Finally, recent intervention studies have also focused on frailty. Participation in exercise programs, including chair-based, strength, or aerobic, appears to positively impact frailty by improving physical functioning, strength, balance, and quality of life.

Other areas that have been less frequently studied in which exercise has the potential to positively influence health include cancer, stroke, disability, and cognitive impairments. While few studies have been conducted among older adults with cancer, the effects appear promising. Thus far, studies have shown that exercise has the potential to decrease fatigue; promote weight loss; improve health-related quality of life, physical functioning, and mood; and modify coronary heart disease risk factors. More research needs to be done on the long-term effects of exercise on cancer recurrence and reduction of cancer-related risk factors, as well as on the optimal dose of exercise needed to improve the health, physical functioning, and psychological status of individuals with cancer. Likewise, few randomized trials have been conducted among people who have had strokes, and the evidence to support the efficacy of aerobic exercise in stroke is insufficient. Related to cognitive function, aerobic interventions have been shown to have a positive impact on executive function in older adults. More intervention research is warranted for areas of study in which little is known about how to determine the optimal dose, intensity and duration of exercise to maximize the health outcomes, and what characteristics of the program and/or setting influence exercise intervention participation.

The effect of exercise on mental health status has also been examined. While the evidence of the association between physical inactivity and depressive symptoms in older adults is strong, the evidence of a direct causal role of physical activity on reducing depression is promising but insufficient at this time. In a review of exercise training and depression in older adults, it was reported that exercise reduces depressive symptoms in older adults but not significantly more so than health education/social control referent groups. However, one study reported that aerobic exercise significantly reduced depression and was just as effective as antidepressant medication in older adults. Given the high prevalence of depression among older adults and the impact of depression on health and well-being, additional randomized trials examining the role of aerobic and resistance exercise on depression are warranted.

While an abundance of intervention research has been conducted, one caveat to the research is that the majority of the interventions have been premised on the current recommendations for physical activity. Most interventions have encouraged participants to engage in moderate-intensity exercise on 5 days/week for at least 30 min/day. Few interventions have tried to manipulate the dose, intensity, or volume of exercise. For example, one study examining cardiovascular risk factors in older adults compared high-intensity group or home-based exercise (3 days/week for 40 min at 73–88% peak treadmill heart rate) to moderate-intensity home-based exercise (5 days/week for 30 min at 60–73% peak treadmill heart rate). All three groups showed improvements in fitness but not

high-density lipoprotein (HDL) cholesterol at the end of year one. After 2 years, both home-based groups showed improvements in HDL levels; however, the improvements were more pronounced in the lower-intensity group, indicating that a greater frequency of exercise is associated with more favorable improvements in cholesterol. Because few studies have attempted to manipulate physical activity parameters, it is unknown whether some individuals could benefit from a lower dose of physical activity or how these individuals may differ from individuals requiring higher doses of physical activity. It is also not known how different diseases will respond to varying amounts of exercise. Future research studies should focus on manipulating the dose, intensity, frequency, or volume of exercise to get a better understanding of the dose response necessary to improve health within different diseases and within different subpopulations.

Correlates of Physical Activity

A considerable body of literature has been generated as to the underlying determinants associated with regular physical activity among older adults. These factors can be organized into three general domains: (1) psychosocial social and motivational factors, (2) environmental factors, and (3) exercise program characteristics. These correlates have been examined in those who do and do not exercise and in studies examining the initiation and maintenance of regular physical activity. Except for the psychosocial determinants of physical activity, relatively few of these studies have examined the causal relationship through randomized control studies.

Important motivational determinants of physical activity include self-efficacy, social support, concerns about safety, performance feedback, and related perceptions and beliefs. Self-efficacy for exercise is one of the most investigated and strongest motivational determinants of exercise. Older adults are more likely to start and maintain exercise activities when they feel they are capable of performing the exercise and when they are able to perform the exercise with no health risk. Concerns related to self-efficacy are particularly important among frail older adults and those with chronic illnesses. Perceptions of outcome efficacy (beliefs of obtaining desired outcomes) are also associated with exercise among older adults. Together, self-efficacy expectancy and outcome efficacy are the foundation for social cognitive theory, which is the most common theory guiding exercise programs for older adults.

Social support is another determinant of exercise for older adults. Observational studies have demonstrated that support for exercise from family and friends is associated with increased physical activity. Programs that include a social support component (e.g., an exercise partner) contribute to adherence to exercise routines. Related to social support, positive reinforcement also contributes to adherence with exercise and physical activity among older individuals. Examples of reinforcement strategies used in exercise programs include telephone-delivered motivational counseling, recognition of attendance and accomplishments, and the inherent positive feedback when the person becomes aware of the health benefits of exercise participation. Regular physical activity is more likely to occur and be maintained for older individuals when multiple psychosocial motivational techniques are used.

Finally, knowledge about physical activity and beliefs about the benefits of exercise are associated with physical activity. Those who perceive greater benefits of exercise and fewer barriers are more likely to participate in regular physical activity. Also, poor health and functional status and concerns about one's health result in a greater likelihood of declining participation in and non-adherence to exercise programs.

Several environmental barriers to regular physical activity have been identified among older populations. In terms of walking for exercise, older adults report barriers in both the built and natural environment. Concerns for safety, a lack of enjoyable scenery, and neighborhood characteristics (e.g., hills, unattended dogs, not seeing others walking for exercise) are associated with less walking for exercise among older persons. As might be expected, accessibility to desired locations such as a beach or park promotes walking. Being within walking distance (i.e., within one half mile) to businesses also facilitates destination walking. Elderly in lower socioeconomic status (SES) neighborhoods walked more than those in higher SES neighborhoods. Finally, several of these environmental factors (e.g., weather, neighborhood walking) have also been associated with adherence to group-based exercise programs with older women.

In terms of exercise program characteristics, there is some evidence that older women prefer home-based over group-based physical activity programs. Evidence suggests that the majority of older adults prefer programs that are lower in intensity and convenient.

Life Span Transitions and Physical Activity

How life span transitions may influence physical activity among older adults is just beginning to be

understood. Major life transitions such as loss of spouse, retirement, and becoming a caregiver are associated with changes in perceptions of self, changes in social roles and responsibilities, and changes in resources – all potentially affecting physical activity. Decreases in physical activity have been associated with the onset of the caregiver role. A major reason for exercise program attrition among minority older adults is due to becoming a caregiver. Older adults faced with other priorities and increased responsibilities report limited time for physical activity. The association between physical activity and marital status has been mixed. However, there is evidence that older women who lose their spouse and remain unmarried report a slight increase in physical activity. Compared to older persons who continue working, a greater percentage of those who retire participate in regular physical activity and leisure walking. This increase was reported for African American and Caucasian as well as female and male older adults. Vigorous physical activity does not significantly increase with retirement. Causes for changes in physical activity among these life span transitions are not well understood. Additional research should be directed at identifying the underlying mechanisms accounting for the changes in physical activity.

Settings for Physical Activity among Older Adults

Crucial to designing effective interventions among older adults is the need to understand what settings older adults encounter during their daily routine that could be used as a place to promote physical activity. Ideally, to enhance the likelihood of success for community-based physical activity programs, interventionists should utilize the facilities within communities that are frequented by the target population. For older adults, there are several settings that could easily be used as locations for an intervention. Senior or congregational meal centers are highly utilized by the older adult population. Many senior centers already have fitness equipment as part of their setting, making them an ideal place to offer fitness programs for older adults. The Fit and Strong Program is one example of an intervention that successfully used senior centers to increase physical activity among people with arthritis. Assisted living facilities, retirement communities, and nursing homes provide another setting for targeting older adults. These settings provide the benefit of targeting individuals who are frail and impaired and most in need of physical activity. For example, assisted living facilities would provide an ideal setting to promote chair-based exercise interventions and interventions aimed at reducing falls and improving physical function. Church-based programs have been successfully used to increase physical activity in older adults. The efficacy of tailoring physical activity programs to African American adults within the church setting and the feasibility of using churches to engage older African Americans in physical activity have been demonstrated.

Other community-based settings that have potential to increase physical activity include malls, fitness centers and gyms, and parks. Many malls offer walking programs and clubs, and malls are cited by 37% of people who walk as a preferred location for walking. Malls are temperature controlled and offer a safe environment for physical activity. Increasing the availability of exercise programs for seniors at local fitness centers, gyms, and recreation centers may also be important for increasing physical activity. While there is a preponderance of fitness centers, few offer affordable programs tailored to the needs of older adults. Increasing the presence of senior fitness programming may help to increase exercise participation.

The health-care provider's office is also an ideal setting for promoting physical activity to older adults. The average adult visits their physician three times per year. Due to the substantial burden of chronic illnesses among older adults and the likelihood of them visiting their primary care physician to manage these illnesses, the physician's office should be a primary source of information about exercise. However, national data indicate that only 31% of adults over the age of 65 actually receive advice from their physician to increase their exercise level. In 2002, the United States Preventive Services Task Force found insufficient evidence to recommend for or against behavioral counseling for physical activity in the doctor's office. The reason for this finding rested primarily on the lack of evidence for a sustained effect on physical activity and the mixed quality of the studies. However, this does not mean that physician counseling is ineffective. Further, the report suggests that higher-quality research is needed and that a better understanding of the intensity of the physician counseling is needed to promote physical activity as part of this research. For example, one recent randomized trial found that older adults who received both advice from a physician and telephone-based exercise counseling increased their physical activity more than those individuals who received solely physician counseling.

Due to the high levels of frailty and social isolation among older adults, the home cannot be ignored as a setting for promoting physical activity. Simple chair-based exercise programs such as Strong for Life have

been developed for frail older individuals who are homebound. This program was found to be efficacious in clinical trials and was also successfully disseminated through community-based social service agencies. The fact that Strong for Life is based on videotapes and uses easily obtainable equipment, Therabands, makes it an ideal option for increasing physical activity among homebound older adults.

Evidence-Based Physical Activity Programs

The field of physical activity promotion for older adults has become more sophisticated over the years, transitioning from an individualized approach for increasing physical activity to a more ecological approach. Efforts to increase physical activity at the community level have been advanced by the development of the National Blueprint for Increasing Physical Activity among Adults Age 50 and Older, which provides a comprehensive framework for groups interested in helping adults 50 and older start and maintain an exercise program. **Table 1** provides examples of effective, evidence-based physical activity programs. To date, the majority of community-based programs promoting physical activity have focused on changing individual behavior within a community-based setting. These individually based programs have typically been designed to examine how physical activity can improve fitness, function, or health, or they have used a lifestyle approach in which participants are encouraged to accumulate 30 min of moderate-intensity activity on at least 5 days per week. Important to the design of the lifestyle intervention approach is the issue of choice. The participants in lifestyle interventions are encouraged to choose the type of activity in which they would like to engage (e.g., existing programs within the community or exercising at home) rather than having the type of exercise predetermined. Other suggested forms of community-based interventions include the dissemination of established successful programs into community-based settings and changing the context or the environment of settings to enhance physical activity. However, few studies have been done on examining the dissemination of evidence-based programs or on changing the environment to increase physical activity for adults. A better understanding of the practicality of disseminating evidence-based programs and the

Table 1 Examples of evidence-based physical activity programs

Program name	*Author(s)*	*Target population*	*Current dissemination status*
Active Choices	Stanford Prevention Research Center	Middle-age to older adults	Widely disseminated program in more than 25 community and health settings; dissemination within senior centers currently being evaluated
Active Living Everyday	Blair SN, Dunn A, Marcus B, Carpenter R, and Jaret P	Sedentary adults (of all ages)	Widely disseminated by a variety of organizations such as worksites, hospitals, community health programs and colleges, and senior residences; dissemination within senior centers currently being evaluated
CHAMPS	Stewart AL, Mills KM, Sepsis PG, King AC, *et al.*	Older adults (65 +)	Tested in senior centers, congregate homes, and physician offices
Fit and Strong	Hughes S, Seymour R, Campbell R, *et al.*	Adults with arthritis	Currently being disseminated to senior centers within the Chicago area as part of a dissemination trial
PACE (People with Arthritis Can Exercise)	Arthritis Foundation	Adults with arthritis	Widely disseminated to individuals and within community-based settings via the Arthritis Foundation; effectiveness trial currently in progress
Strong for Life	Jette AM, Harris BA, Sleeper L, *et al.*	Homebound, frail seniors	Large-scale dissemination is planned within the state of Illinois

Table 2 Summary gaps in research on physical activity and aging

1. Limited research on physical activity among diverse ethnic older populations, including Hispanic, Asian, and American Indian older adults
2. Little understanding as to how life transitions (e.g., retirement, loss of spouse, caregiver status) may influence physical activity
3. Need to understand the benefits of physical activity on persons with chronic illnesses such as cancer, cognitive impairment, stroke, and disability
4. Need for information on factors associated with long-term adherence to exercise and an active lifestyle
5. Limited information on the dose–response effect of exercise among older adults, especially among those with a chronic condition or multiple chronic conditions
6. Minimal understanding of how settings and environments influence physical activity
7. Need for a broader set of measures to evaluate the impact of physical activity focusing on the priorities of older exercise participant and the agency/community groups providing the programs
8. Need for research on effective strategies for translation and dissemination of physical activity programs with proven efficacy and effectiveness

environmental aspects related to physical activity promotion is needed.

Summary and Conclusions

The research base for physical activity among older adults allows for several conclusions on what is and is not known. To review, there are considerable data on the prevalence of specific types of physical activity among a variety of groups of older adults. There is also considerable information on the determinants of physical activity and exercise in older populations, especially the social cognitive factors motivating the onset and maintenance of physical activity. There is also strong evidence on the benefits of specific forms of physical activity among healthy older adults and those with specific chronic illnesses such as arthritis, diabetes, and hypertension. Finally, the field has made considerable progress in designing comprehensive community-based physical activity programs for older adults based on randomized intervention trial findings demonstrating efficacy and effectiveness.

While significant progress has been made, major gaps in the research remain. **Table 2** provides a summary of the gaps addressed in this article. As noted earlier, the majority of the research on physical activity with older adults is based primarily on white and female groups and, to some degree, older African Americans. The lack of information on physical activity among other minority groups such as Hispanic and Asian older adults is a major gap given the growing ethnic diversity of the older population. Research on physical activity and life transitions is in an early stage of development and should be promoted given the potential changes in physical activity noted. Also, a life transition approach would promote tailored interventions specific to the needs of older adults. An important advancement in exercise with older adults is the effort to examine the benefits of exercise among older adults selected based on specific chronic illnesses. This research has focused on a select few chronic illnesses and could easily be expanded to address a broader set of chronic conditions. This research should include primary prevention as well as secondary and tertiary prevention intervention.

With few exceptions, the majority of exercise intervention trials have examined adherence over a limited time frame (1 year to 18 months). There is a need to better understand how a long-term lifestyle change in physical activity can be promoted among older adults in order to obtain lasting health benefits and improvement in disability. Many older adults will not reach the recommended levels of physical activity, and yet may benefit from some level of activity. Also, some may obtain benefits with less than recommended levels of exercise intensity, duration, and frequency. Additional research should focus on the dose–effect of exercise among older adults so they are better informed about the value of less than ideal activity. As noted earlier, characteristics of the built and natural environment influence physical activity among older adults. Research on the role of the environment in physical activity for older adults is just beginning. Concerns over the person–environment fit are particularly relevant for older adults due to functional limitations (e.g., vision, gait alterations, and balance).

To date, physical activity and exercise programs have focused on outcomes based primarily on measures used in research (e.g., $VO_{2\ max}$, timed chair rise, 6-min walk). As exercise programs move from clinical trials to community-based programs, additional effort should be directed to focusing on outcomes meaningful to the older participant. Tailoring outcomes to the priority of the older participant will help to promote outcome efficacy, thereby increasing exercise adherence. Finally, there are several quality comprehensive physical activity programs with proven effectiveness and efficacy. These community-based

programs are at various stages of diffusion and dissemination into the wider community. Additional research should focus on the most effective strategies for bringing these programs to targeted older adults in various community settings. Addressing this as well as the other gaps noted in **Table 2** should increase the proportion of older adults participating in regular physical activity and will contribute greatly to the health and well-being of older adults.

See also: Disability, Functional Status and Activities of Daily Living; Frail Elderly; Mobility and Flexibility; Self-Regulation, Health, and Behavior.

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Extracellular Matrix

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Glossary

Collagen – Family of large structural proteins, characterized by triple helix conformation, which provide tensile strength to tissues and organs and serve as a matrix for growth and proliferation of cells.

Elastin – Highly insoluble structural protein capable of reversible expansion and contraction, essential for physiological functioning of deformable tissues such as blood vessels, skin, and lung.

Extracellular Matrix – Intricate network composed of the structural proteins collagen and elastin in association with proteoglycans that serves as the scaffolding for tissues and organs throughout the body.

Proteoglycan – Family of non-fibrillar connective tissue components associated with collagen and elastin in the extracellular space, consisting of a core protein with one or more glycosaminoglycan side chains covalently attached.

Introduction

The extracellular matrix serves as the scaffolding for tissues and organs throughout the body, playing an essential role in their structural and functional integrity. Its predominant components are the large, insoluble structural proteins collagen and elastin. Although the matrix was originally thought to be relatively inert, it is now apparent that the matrix undergoes profound structural changes are over time. Much progress has been made recently in understanding the molecular basis of these changes, despite formidable technical difficulties in analyzing the matrix proteins. The mechanisms responsible for matrix alterations are also still poorly understood. Although we know that some of these structural changes are under genetic control, many are not, such as the series of reactions between matrix proteins and sugar molecules to form complex colored and fluorescent compounds. As the matrix structure changes over time, so do its physical and chemical properties, such as solubility, flexibility, and mechanical strength. As a result, tissues and organs throughout the body also undergo changes in structure and function. In addition, age-associated changes in matrix affect key properties of the resident cell populations. In summary, many changes we associate with the aging process are attributable either directly or indirectly to cumulative structural changes in the extracellular matrix.

Introduction: Why Is Aging of the Extracellular Matrix Important?

Aging is characterized by profound changes in the extracellular matrix, the complex network of long-lived structural proteins and glycosaminoglycans that serves as the scaffolding for virtually every tissue and organ system. It has long been postulated that the process of matrix aging may have more than phenomenological significance, and that within its intertwined pattern of cause and effect may lie the key to understanding fundamental mechanisms of aging in the organism as a whole. One of the earliest unifying hypotheses of aging, advanced almost 50 years ago, proposed that aging was initiated by the development of irreversible cross-links in matrix macromolecules that accumulated over time and led inexorably to the degenerative changes associated with aging. In these early studies, structural changes in matrix macromolecules were inferred from changes in their physicochemical properties. Since then, the tools of modern molecular biology have begun to reveal the molecular basis for many age-associated phenomena previously observed only at the microscopic and macroscopic level. Recent studies suggest that the original concept that the matrix might serve as a kind of clock that both regulates and reveals biological age retains considerable validity.

Why is the matrix so suited to the role of biological timekeeper? First, the matrix is truly the common ground of an organism, present in all tissues and organs from the earliest developmental stages until death. Second, the two major matrix proteins, collagen and elastin, have extremely long half-lives *in vivo*. Third, collagen and elastin are subject to extensive post-translational modification, ranging from hydroxylation and glycation of individual residues to the formation of complex cross-links and adducts. Few other proteins besides collagen and elastin possess all three of these qualities: ubiquity, longevity, and plasticity. How are these characteristics related to aging? The long half-life of these proteins means that a given molecule may continue to undergo structural modification over many years. As a consequence, the collagen and elastin molecules in an individual organism accumulate a set of modifications that serve as a kind of permanent record of the innumerable interactions between the organism, with its unique genetic endowment, and its uniquely experienced environment. This record, however, is far from inert. As the matrix changes, so does its effect on proliferation, migration, response to cytokines, and gene expression of resident cell populations. Age-associated changes in matrix also profoundly affect tissue and organ system function. Because of the ubiquity of matrix, these effects on cells and tissues occur throughout the body, ultimately affecting the organism at the systemic level. Thus, the molecular memory of an organism's experience in the world, recorded in the code of matrix modification, assumes increasing power to direct that experience; it is this transit – from recorder of events to regulator – that lies at the heart of the aging process in matrix. To the extent that we can learn the language of matrix memory, we may find new ways to change the message that has, thus far, been so inexorably determined by the passage of time.

Assessment of Matrix Aging: Commonly Used Methodologies

Our conceptual understanding about a phenomenon is often shaped by the tools available for investigation and by the choice of tools used. The investigation of matrix aging provides a particularly apt illustration of the pitfalls that can occur when the limitations of analytic techniques are ignored or, worse, when these very limitations have been mistakenly used to draw inferences about the subject of study. Even a cursory examination of the primary literature

on matrix aging reveals a vast number of contradictory reports. Some of the inconsistencies are attributable to differences in study design (particularly differences in the age range of animals studied), whereas some are due to methodological shortcomings, including failure to recognize inherent limitations, failure to recognize implicit assumptions in the assay of choice, and, as a consequence, failure to consider alternative explanations for a particular finding. Thus, before one can attempt to draw any general conclusions from the very large literature, one must have some understanding of the rationale for the limitations of commonly used analytical techniques used in studying the effects of aging on the matrix.

Histochemistry

Light microscopy is one of the oldest techniques for studying the effects of aging on the extracellular matrix proteins. Although qualitative information can be obtained that may be helpful in determining experimental strategies, there are many pitfalls that significantly limit the conclusions that can be drawn from such data. In older studies, histochemical studies using non-specific stains such as hemotoxylin-eosin were sometimes used to investigate the effects of age on the amount and distribution of collagen in different tissues. Discrepancies between such studies are most likely due to the lack of consensus concerning the definition of collagen fibers, differences in staining techniques, and differences in tissue preparation. Attempts have also been made to categorize components of the matrix on the basis of their staining properties, giving rise to distinctions between such entities as reticulin, collastin, and basement membrane collagen. Again, there is little consensus as to the definition of such terms. More recently, the discovery that many tissues were composed of more than one genetically distinct collagen aroused interest in the use of special stains that were believed to have specificity for a particular collagen type. Mason's trichrome and van Gieson's stain are generally assumed to be specific for type I collagen, whereas Gomori's stain (silver impregnation) has been referred to as type III specific. However, it is now evident that these stains cannot be used for quantitative assessment of changes in collagen type distribution due to inconsistencies in their ability to stain specific collagen types. For example, silver impregnation is capable of staining newly synthesized type I collagen, but not mature fibrils. Furthermore, the staining properties of the more recently discovered collagen types (types V–VI) are unknown. Although there have been attempts to develop more elaborate panels of staining procedures that could be correlated with different collagen types, this approach seems particularly fruitless given the ever-increasing number of genetically distinct collagen types being identified.

Histological assessment of age-associated changes in elastin poses equally difficult problems. Historically, elastic fibers have been characterized by their ability to take up such stains as Verhoeff-hematoxylin, resorcin-fuchsin, and orcein, due to the presence of aldehyde groups and/or strongly hydrophobic regions. However, although some investigators draw inferences about elastin from the use of such stains, it should be emphasized that elastic fibers are not synonymous with elastin. Elastic fibers have been shown to be composed of elastin and elastic fiber microfibrils, which in turn comprise several genetically distinct proteins, including fibrillin and the so-called microfibrillar-associated proteins. There is at present little information as to how these microfibrillar components interact with and affect elastin structure. Thus, histochemical studies of age-associated changes in elastic fibers cannot be construed as providing much structural information as to what happens to elastin during aging.

Finally, there are several general limitations inherent in any type of histological assessment of the effects of aging on matrix. First, it is very likely that the staining properties of collagen and elastin are affected by the profound structural changes that occur with aging, thus making it questionable whether young and old tissue can be directly compared by histochemical techniques. However, no data are available concerning this issue. Second, problems in true random sampling and quantification of staining intensity further reduce the usefulness of histological techniques in assessing age-associated changes in matrix.

Mechanical Properties

Histochemical studies are clearly limited by their descriptive nature and by their inability to provide either precise quantitative data or information about events in the matrix occurring at the molecular level. In contrast, mechanical properties can be measured very precisely in collagen. Furthermore, changes in such mechanical properties as thermal contraction force, ultimate load, tensile strength, breaking strength, and strain may be assumed to reflect changes at the molecular level. Thus, the hypothesis that aging resulted from irreversible cross-linking of macromolecules provoked considerable interest in investigating the effects of aging on the mechanical properties of collagen. If indeed progressive cross-linking is a

central event in the aging process, then an assay that indirectly reflected degree of cross-linking might have predictive value as a marker of longevity. However, although numerous studies have shown that mechanical properties such as thermal break time are highly correlated with chronological age within a given species, there are no convincing data that these parameters are correlated with longevity.

One of the major disadvantages of these mechanical assays is the necessity of obtaining collagen in fiber form, as most collagen in the body cannot be isolated as intact fibers, nor can elastin, due to its extreme insolubility. Thus, the lack of correlation between mechanical properties of collagen and longevity may arise from the fact that only fibrillar type I collagen present in tendon is being assessed. It is possible that changes in mechanical properties in this collagen do not accurately reflect age-associated changes occurring in parenchymal tissue containing complex mixtures of fibrillar and non-fibrillar collagen types.

Solubility

In part to circumvent the limitations inherent in assays of mechanical properties, several investigators developed methods for precise quantification of collagen solubility, a parameter that has long been observed to increase with age. Urea, neutral salt buffers, and acids of varying strength have all been used to solubilize collagen. Rate of solubilization by enzymatic digestion has also been extensively used, sometimes with enzymes such as pepsin, which are not specific for collagen, but more often with highly purified collagenase. Solubilization is significantly correlated with chronological age within a given species. However, attempts to correlate solubility with longevity have not been as fruitful. Furthermore, studies have also shown that results obtained with one solubilizing agent may not be consistent with results obtained using another. For example, collagenase digestibility of rat collagen decreases very little after rats reach maturity, whereas solubility in urea decreases markedly with age. This discrepancy between effects of different solubilizing agents was not observed in longer lived species such as humans, monkeys, and dogs, raising the possibility that extrapolation from data obtained in a short-lived species to a long-lived species must be done cautiously.

Electron Microscopy

Advances in electron microscopy and the development of quantitative morphometric techniques have provided potentially powerful new analytical tools for analyzing the effects of aging. However, this analytical approach suffers from some of the same problems as light microscopy, in that a terminology has developed based upon descriptive features rather than on well-defined chemical entities. The relationship of such terms as unit collagen fibrils, microfibrils, reticular fibers, and primary fibrils to molecular concepts of collagen structure remains very unclear, despite attempts to correlate fibril diameter with collagen type, degree of glycosylation, and composition of intervening ground substance.

Electron microscopy has perhaps been most fruitful when used in conjunction with X-ray diffraction studies and chemical analyses in elucidating the molecular structure of collagen fibrils. Collagen exists *in vivo* in the form of fibrils measuring 50–2000 Å. Both low angle X-ray diffraction and electron microscopy indicate an axial period of about 640 Å, within which characteristic repeating bands can be observed after staining. These striations within a period result from the distribution of charged residues, whereas the periodicity results from the self-assembly of tropocollagen units during fibrillogenesis into five-stranded helical microfibrils, in which each tropocollagen unit overlaps its neighbors by a multiple of the distance 640 Å (the quarter-stagger model). The native fibril consists of aligned microfibrils packed side to side; presumably other types of fibrils result from different arrangements of the microfibrils or from interactions with other macromolecular components of the matrix. This type of integrated approach is being used to analyze the changes in molecular packing that result from the post-translational changes that occur during aging. For example, it has been shown that nonenzymatic glycation leads to expansion of the microfibrillar assembly.

Biochemical Studies

During the last 20 years, the explosion of knowledge in biochemistry and molecular biology has resulted in the development of many new methods for studying the effects of aging on synthesis and deposition of matrix proteins. As with other approaches, there are many methodological pitfalls in commonly used biochemical assays that can seriously skew the data, and which have resulted in conflicting reports about the effects of aging on virtually every aspect of matrix biosynthesis.

Collagen Content Early methods for measuring collagen content of tissues such as gelatinization or hot trichloroacetic acid precipitation are not very precise. One of the first specific assays developed for

measuring collagen involves quantifying hydroxyproline, an amino acid residue that comprises approximately 15% of the total amino acids present in collagen. Hydroxyproline is, for most purposes, a reasonably specific marker for collagen, as the amount present in elastin and in the Clq component of complement – the only two other potential sources – is negligible by comparison. Assays based upon oxidation of hydroxyproline to pyrrole, which is quantified colorimetrically, are most often used. Even in this fairly straightforward assay there may be pitfalls, particularly with respect to selecting an appropriate denominator term. If hydroxyproline is expressed as a concentration (per unit tissue weight or unit tissue volume, per gram of total protein or DNA, for example) rather than on a per organ basis, net changes in total collagen may be masked by the effects of age on the denominator term. It may be impossible to compare studies using different denominator terms, as different results may be obtained. Hydroxyproline values may also be significantly affected by tissue preparation; for example, tissues that are either edematous or contaminated with blood may give falsely high values in this assay, as colored impurities from heme absorb light at the same wavelength as the pyrrole chromophore. Gross contamination of a sample with blood, on the other hand, may result in spuriously low values.

Elastin Content Elastin has been less well defined chemically than collagen, in part because, unlike collagen, it is extremely difficult to solubilize in intact form. As a consequence, many approaches have been developed for biochemically measuring elastin, resulting in widely variable estimations of elastin content for several tissues and organs. For example, estimations of lung elastin content vary from 1 to 47%, depending on the assay used, as illustrated in **Table 1**. Probably the most commonly used method for quantitating elastin is the Lansing procedure, in which elastin is isolated on the basis of its insolubility in boiling sodium hydroxide. Several variations of the method exist in which insoluble non-elastin material is separated from elastin in the final precipitate, including solubilization of elastin with potassium hydroxide (KOH) and elastase digestion. Another approach is to measure nitrogen content of the final precipitate and assume elastin is 16.34% nitrogen. Enzymatic methods for quantitating elastin have also been used, such as digestion of crude tissue preparations with trypsin and collagenase to remove non-elastin proteins. More elaborate versions of this method include sequential treatment of tissue with guanidine, collagenase, guanidine plus a reducing agent, and 6 M urea with sodium dodecylsulfate. All of these methods suffer from the potential loss of elastin during the harsh extraction procedures or the persistence of non-elastin material in the final product. These difficulties are especially pronounced when examining complex tissues and organs containing multiple matrix components. Quantification of elastin by measuring its unique cross-links, desmosine and isodesmodine, have been used as an alternative approach that avoids the problem of including non-elastin material in the final calculation. However, the implicit assumption is that the elastin being quantitated is fully cross-linked, and that the number of desmosines per chain is constant.

Table 1 Effects of aging on elastin content of human lung

Age (years)	*Elastin (% dry wt)*	*Effect of age*	*Assay technique*
2–80	1–13	↑	Lansing
1–65	8–15	↑	Acetone extraction, Lansing
19–92	35–47	↑	Cold alkali or ether extraction, autoclave
15–83	8	→	Lansing, expressed per unit volume
15–83	8	↑	Lansing, expressed per mg tissue
41–71	18	→	Nitrogen content of insoluble lung

Collagen Synthesis and Turnover In addition to serving as a marker for collagen content, hydroxyproline also provides a useful marker for measuring collagen synthesis. The effects of age on collagen synthesis have been studied *in vitro* using short-term tissue explants. If radiolabeled proline is used as the isotope, the accumulation of labeled hydroxyproline during a defined time period provides a good index of the extent of collagen synthesis. Rate of collagen synthesis (generally expressed as microgram of labeled hydroxyproline per gram of protein per hour) can also be determined using these techniques. Potential sources of trouble in this assay in tissue explants include unexpected effects of age on the precursor proline pool size in a given tissue or organ and failure to distinguish between changes in synthesis and changes in intracellular degradation.

In contrast to the relatively straightforward techniques used to study the effects of aging on collagen synthesis *in vitro*, studies of collagen biosynthesis *in vivo* represent one of the most contentious areas of investigation, with wildly divergent conclusions regarding the stability of the matrix. At issue is the question of how collagen ages: is some or all of the

collagen that is synthesized when the animal is young present in old age? Alternatively, is all of the collagen in the body in a state of dynamic equilibrium? Despite decades of investigation, this issue remains far from resolved. Perhaps this is not surprising in view of the difficulties in designing experiments free of artifact, as well as in unambiguously interpreting the data from such experiments. Early studies on collagen metabolism and turnover supported the notion that there might be a pool of immortal collagen that is present in the organism throughout life and that becomes increasingly cross-linked over time, thus accounting for the progressive changes associated with aging. Such studies generally involved long-term pulse-decay experiments with labeled amino acids, such as proline, lysine, or glycine. Label reutilization appeared to be minimal, based on plasma-specific activities determined less than 1 week after injection. These conclusions regarding collagen turnover were seriously questioned when studies showed that label recycling, particularly of proline, might be much greater than originally estimated. Several new approaches were developed to circumvent the problem of label recycling, many of which are still in use. One approach involves repeated administration of the labeled precursor during the period of rapid growth, either immediately postnatally or *in utero* and then waiting until the animal is middle-aged or older to harvest tissue. Variations of pulse-chase techniques have also been used to minimize label recycling, including the administration of very large doses of unlabeled precursor to dilute any recycled label. Some investigators utilizing such pool expansion techniques have concluded that the matrix, far from containing immortal pools, seems almost volcanic in its constant activity, with rapid turnover of collagen throughout adulthood. These conclusions, however, directly contradict studies of turnover utilizing a very different approach: tracking the metabolic fate of collagen labeled with ^{18}O, a radiolabeled precursor that by definition cannot be recycled at all. Studies using ^{18}O labeling in rodents provided definitive proof that some of the collagen molecules that are synthesized during the neonatal period are still present in old age, and are found exclusively in the pool of insoluble collagen, thus suggesting they have undergone progressive cross-linking. How can we reconcile these observations with the data obtained from the pool expansion approach? It is possible that flooding the animal with unphysiological doses of the unlabeled precursor amino acids may affect collagen metabolism in some way. However, the simplest explanation is that the pool expansion data have been erroneously interpreted. Because these techniques do not distinguish between intracellular and extracellular collagen, it is likely that the extremely rapid turnover of label does not reflect turnover of matrix collagen, but rather the very rapid intracellular breakdown of procollagen (collagen that still has extension peptides attached to it) before it is even secreted from the cell. Rapid intracellular degradation of procollagen has been reported in all connective tissue cells, with levels of breakdown ranging from 10 to 40% of newly synthesized procollagen.

Interestingly, there has been far less disagreement concerning elastin turnover, although presumably some of the concerns regarding label reutilization are similar. Most studies have shown that turnover is extremely slow, and best measured in years.

Enzymatically Mediated Cross-links The elucidation of cross-linking pathways in collagen and elastin and structural characterization of specific cross-links has led to a particularly intriguing area of investigation. The first step in cross-link formation is the oxidative deamination of epsilon amino groups on selected lysine residues (and hydroxylysine residues in collagen) by the extracellular enzyme lysyl oxidase. The resultant aldehydes are then capable of undergoing further reactions with unmodified lysine and hydroxylysine residues to form cross-links characterized by a Schiff base-type double bond. Further stabilization of these cross-links occurs through rearrangement and additional reactions to form tri- and tetrafunctional cross-links. Formation of these cross-links is tightly regulated, as they are synthesized at only one or two sites on the chain. Although collagen and elastin have similar cross-linking pathways, elastin lacks any cross-links derived from hydroxylysine; in addition, elastin contains two mature cross-links not found in collagen, desmosine or isodesmosine.

Accurate quantification of cross-links was initially hindered by their scarcity: there may be only one cross-link residue for every 6000 to 10 000 amino acids. However, the development of high-pressure liquid chromatography led to the development of relatively rapid and accurate techniques for quantifying almost all of the structurally characterized cross-links. Despite these technological advances, there remain many pitfalls in the analysis of cross-links, which most likely account for the conflicting results concerning amounts of cross-links in different tissues and species. Accurate assessment requires rigorous attention to standard preparation, including use of standards to control for variability at all stages of analysis from tissue preparation through hydrolysis; analysis of effective reducing capacity of every isotope batch used for reductive labeling; frequent checks of column efficiency and column regeneration

or replacement as soon as performance decrement is noted.

Studies of the effects of aging on enzymatically mediated cross-links led to somewhat surprising results. The reducible cross-links, so called because of their characteristic Schiff base-type double bond, were found to decrease rapidly during the postnatal period in most tissues and species. Known maturational products of these cross-links, the tri- and tetrafunctional cross-links, were found, in many cases, to show a corresponding increase in number during this time. However, these so-called mature cross-links did not continue to increase throughout the life span; in many cases, they leveled off or even declined in number during old age. Thus, although enzymatic cross-linking clearly underwent changes with age, the magnitude of these changes, particularly during the last part of the life span, did not seem to correlate with the progressive changes in physicochemical properties of the matrix. Many attempts were made to discover novel mature cross-links that could account for the observed changes in matrix associated with aging. Based on indirect evidence, entities such as compound M, poly CB-6, and the Ehrlich chromogen have been suggested at various times as possible candidates. These studies illustrate an important caveat concerning identification of a compound as a cross-link: unless a compound can be directly shown to link two collagen chains (i.e., through sequential digestion, such that one can show that the putative cross-link joins peptide fragments from two separate chains), it cannot be considered a proven cross-link.

Sugar-Derived Cross-links The hypothesis that progressive, irreversible cross-linking was a key feature of aging appeared to be inconsistent with the studies reporting that lysyl oxidase-mediated cross-links showed relatively few changes near the end of the life span. However, cross-links have been identified in collagen that arise from an entirely different pathway, in which the initiating event is the non-enzymatic addition of sugar molecules to lysine and hydroxylysine residues. The sugar adducts then undergo fragmentation to form deoxyglucosones. These highly reactive compounds serve as propagators of a series of reactions that ultimately generate an array of fluorophores and chromophores known collectively as advanced Maillard products or advanced glycation products. Although these reaction pathways have been of considerable interest to food chemists since the turn of the twentieth century, it has only been relatively recently that attention has focused on non-enzymatic glycation of proteins *in vivo*. The effects of glycation on long-lived macromolecules such as collagen have been of particular interest, as it has been shown that glycation affects collagen solubility, tensile strength, rupture time, ability to bind to ligands, and conformation (*see* Glycation).

Early studies of non-enzymatic glycation of matrix reported that aging was associated with increasing levels of glucose adducts on collagen throughout the life span. However, more recent studies by several investigators have not confirmed the earlier reports. These conflicting results are most likely due to differences in the specificity of the analytical techniques used. For example, in many of the earlier studies the investigators used the thiobarbituric acid assay, which is subject to interference by a number of compounds, including free glucose and glycosidically bound carbohydrates. In later studies, more specific techniques have been used for quantification, including the furosine assay and affinity chromatography followed by high-pressure liquid chromatography to isolate the glycated residues. Despite this evidence that the thiobarbituric acid assay is not reliable for quantifying glucose adducts on collagen, it continues to be used for this purpose.

As interest developed in the biological consequences of non-enzymatic glycation of proteins, attention was also focused on maturational products of glycated residues. Although the accumulation of yellow-brown chromophores and fluorophores (browning products) in aging collagen was first reported over 25 years ago, these compounds were initially thought to arise from oxidative reactions of tyrosine residues. The association between browning products and non-enzymatic glycation of collagen has only been investigated relatively recently. In virtually all tissues and species studied, browning products have been found to increase with age. In these studies, the fluorophores and chromophores are inferred to be Maillard products from indirect evidence, such as spectral similarities to known Maillard products or similarities in chromatographic behavior.

Although attempts have been made to characterize specific browning products, isolation and analysis of such compounds as they exist *in vivo* has proven very difficult, owing to low yields, difficulties in isolating the desired compounds, and the ease with which artifacts may be generated. For example, the first report of a structurally characterized advanced glycation product present *in vivo* turned out to be erroneous, for the reported compound was actually an artifact of hydrolysis. In general, unless physiological conditions of temperature and pH are used to isolate putative compounds for analysis, the risk of artifact generation is high; any reports of newly characterized glycation products isolated from tissue

should be cautiously evaluated with this caveat in mind. Only one advanced Maillard product found in collagen *in vivo* has been isolated and fully characterized, a trifunctional fluorophore known as pentosidine. Pentosidine has been shown to increase throughout the life span in several different tissues and species. Pentosidine, however, is present in very low levels (by comparison, enzymatic cross-links are approximately ten times more numerous), thus making it unlikely that pentosidine itself accounts for age-associated changes in the properties of collagen.

Elastin is characterized by a marked degree of autofluorescence, which increases with age in most tissues studied. Whether or not this fluorescence is due to accumulation of advanced glycation products remains unclear, due in part to the extreme difficulty in preparing elastin for analysis without generating artifacts. This fluorescence has been attributed to various compounds such as dityrosine, lipid peroxidation products, quinones, and reactive carbonyl products.

Immunofluorescence

We have seen that one of the major difficulties in correlating histochemical and electron-microscopic analyses of matrix with biochemical analyses has been the discrepancy between descriptive definitions of matrix components based on their visual appearance and structural definitions based on biochemical analysis. To some extent these difficulties are resolved when immunological identification of matrix components has been combined with light or electron microscopy. Immunological probes have been used to identify specific collagen types, specific collagen chains, and even some of the advanced glycation products.

There are a number of antigenic sites in collagen and procollagen (another name for collagen molecules whose extension peptides have not been cleaved), located in both helical and non-helical regions. Because there is cross-species reactivity, antibodies for use in human tissue can, for example, be raised against collagen chains purified from bovine tissue. When purified collagen is used as the antigen for preparation of polyclonal antibodies, the antisera produced contain a high titer of antibody for the immunizing antigen. However, moderate levels of antibody reactive with other collagens or procollagens are also present. Thus, purification on immunoadsorbent columns is essential to remove cross-reacting antibodies, following which the specificity should be documented by passive hemagglutination and by radioimmunoassays.

Antibodies have also been prepared that react with advanced glycation products. The so-called AGE (advanced glycation end product) antibody is prepared by injecting rabbits with glycated albumin; the resultant antibodies react with proteins containing advanced glycation products (as assessed by their fluorescence) but not with unmodified proteins. There is serious question as to the interpretation of data utilizing this antibody. A monoclonal antibody is also available for pyrraline, an advanced glycation product that has only been isolated and characterized from proteins incubated with sugar *in vitro*. Although immunohistochemical analysis of tissues with the pyrraline antibody suggest it is widely distributed *in vivo*, it has proved impossible to isolate it from tissues due to its lability.

Although immunological techniques are a powerful addition to routine histochemistry, there are many potential pitfalls. First of all, the anticollagen antibodies must be highly purified, as any cross-reacting antibodies would render a study virtually useless. Even then, interbatch differences in specificity and affinity of anticollagen antibodies and fluorescein-labeled antibodies means that valid comparisons can only be made within a single series. There is no standardized substrate for validating type-specific antibodies. As noted, there is serious question as to what is actually being detected with the AGE-antibody. Another problem may arise when tissues rich in elastic fibers are analyzed. Such fibers have a strong autofluorescence that may interfere with evaluation of immunofluorescence. Finally, making of antigenic determinants in the tissue to be analyzed can seriously interfere with interpretation of results. It is certainly possible that accessibility of antigenic determinants decreases in old tissue due to blocking by proteoglycans, for example, or the accumulation of glycation products. Finally, there is a large degree of subjectivity in interpretation of results as well as potential problems in random sampling.

Survey of Age-Associated Changes in the Extracellular Matrix

Given the discussion of methodological pitfalls described previously, it is evident that the literature on age-associated changes in the matrix cannot be summarized in a table that restricts itself to a simple listing of species, tissue, parameter, and the effect of aging, although such an approach would make the vast literature seemingly more accessible. Ideally, the validity of each study's conclusions should be considered individually with respect to general pitfalls (age range studied, number of sampling points, adequate sample size for assay variance, particularly if

Table 2 Effects of aging on collagen cross-links in different tissues in mice[a]

Tissue	*Lung*	*Skin*	*Aorta*	*Tail tendon*
DHLNL	↓	nd	↓	nd
HLNL	→	→	↓	↓
OHP	→	nd	↑	nd
Gluc-lys	↓	→	→	→
Fluorescence	—	↑	↑	↑
Pentosidine	—	nd	↑	nd

[a]The cross-link abbreviations are as follows: DHLNL, dihydroxylysinonorleucine (enzyme-mediated difunctional cross-link); HLNL, hydroxylysinonorleucine (enzyme-mediated difunctional cross-link); OHP, hydroxypyridinium (enzyme-mediated fluorescent cross-link); gluc-lys, glucose adduct formed by addition of glucose to lysine residue; fluorescence, collagen-associated fluorescence, assumed to represent advanced glycation products; nd, not detectable; —, no data reported.

Table 3 Effects of aging on collagen cross-links in skin in different species[a]

Species	*HLNL*	*his-HLNL*	*OHP*	*HHMD*
Rat	↓	nd	nd	↓
Mouse	→	nd	nd	↓
Human	↓	↑	↑	↓
Monkey	↓	—	—	↓
Cow	↓	↑	nd	—

[a]The cross-link abbreviations are as follows: HLNL, hydroxylysinonorleucine, (enzyme-mediated difunctional cross-link); his-HLNL, histidinohydroxylysinonorleucine (enzyme-mediated trifunctional cross-link, maturational product of HLNL); HHMD, histidinohydroxymerodesmosine (enzyme-mediated tetrafunctional cross-link); —, no data reported; nd, not detectable.

variance increases with age) and pitfalls specific to the assays used, including a careful consideration of whether other age-associated changes in the organism may interfere with the assay of interest, thus possibly invalidating a comparison of young and old animals.

Despite these difficulties, particularly in comparing one study with another, we can draw several general conclusions: synthesis and deposition of collagen and elastin occur predominantly during the period of early growth and development; synthesis levels then continue at low levels that change little in old age. Collagen becomes progressively more insoluble with age, and autofluorescence increases in both collagen and elastin. Enzymatically mediated cross-links undergo their most significant changes during the first half of the life span in most tissues and species, mature enzymatic cross-links either change little during aging, or sometimes exhibit a biphasic pattern, in which peak levels are reached in middle age, followed by a gradual decrease. In contrast, sugar-derived cross-links accumulate very slowly in most tissues and species during the first half of the life span, with more accelerated accumulation during aging. In some cases significant increases may not occur until the last 10% of the life span. There is considerable species specificity and tissue specificity with respect to both the timing and the magnitude of the changes as illustrated in **Tables 2 and 3**. **Table 2** provides an example of changes in tissues in a single species, and **Table 3** shows changes in a single tissue among several species.

Modulation of Matrix Aging

There has been no shortage of effort expended on discovering a way to slow or reverse aging of the matrix, given that virtually all of the visible signs of aging are attributable to age-associated changes in its components. Approaches may generally be categorized as either replacement strategies or prevention strategies. For example, there has been considerable interest in attempting to slow aging at the systemic level by administration of growth hormone or insulin-like growth factor. There is evidence that some parameters such as muscle mass may increase, and it is possible that stimulating synthesis of new matrix may improve connective tissue function. Adequate long-term studies of the efficacy or safety of these agents are not available.

Preventive strategies have focused on glycation and oxidation as the primary culprits in degenerative changes of the matrix. From this perspective, agents developed for treatment of diabetes (which is characterized by rapid accumulation of advanced glycation products on connective tissue) may have relevance to aging in the normal population. Several agents have been found to inhibit the initial formation of glucose adducts on collagen, including acetylsalicylic acid, acetic anhydride, ibuprofen, glutathione, and the dibasic amino acids lysine and arginine. However, there have been no long-term trials designed to investigate the effects of these agents in aging. Data suggesting that fructation of collagen may contribute to accumulation of browning products have led to an interest in the use of aldose reductase inhibitors to inhibit biosynthesis of fructose. These agents have met with only limited success in diabetes. Recently there has been interest in aminoguanidine, a hydrazine compound that appears to bind to the reactive deoxyglucosones, thus theoretically preventing their progression into more advanced Maillard products. However, conflicting reports regarding its efficacy in preventing diabetic complications have appeared, and long-term safety has not been adequately studied.

Antioxidant administration has also been enjoying a resurgence of interest as antiaging agents. Although

there is some evidence that vitamin E may decrease non-enzymatic glycation of matrix, convincing long-term results are not available. Furthermore, it is unclear that administration of large doses of exogenous antioxidants will alter levels of oxidative stress, due to the tightly regulated homeostatic mechanisms of the antitoxidant defense system.

Dietary manipulation is another approach potential for slowing aging. It has long been known that feeding rodents a diet restricted in calories will extend their life span by about 20%. Very recently it has been shown that such lifetime caloric restriction significantly reduces the accumulation of advanced glycation products on matrix in tissues and organs throughout the body. The relationship between life extension and reduction of advanced glycation products remains to be elucidated. Other dietary manipulations may also be beneficial. Very recent studies have shown that the source of carbohydrate in the diet may significantly influence the accumulation of glycation products in matrix as well as the level of oxidative stress. Rats whose sole source of carbohydrate was fructose had significantly more advanced glycation products on their collagen and significantly higher levels of circulating lipid peroxide products than rats whose carbohydrate source was glucose, even after only 6 months on the special diet. Rats fed mixtures of sugars had intermediate values. Whether these dietary manipulations have similar effects in humans remains to be seen (*see* Diet and Nutrition).

Summary and Conclusions

Given the many caveats regarding methodological pitfalls, species specificity and tissue specificity, are there any generalizations we can make about the effects of age on the extracellular matrix? It is perhaps a truism to say that the more we have learned, the more complex the process appears to be, involving a seemingly endless recursive series of feedback loops between different reaction pathways. However, there are a few general patterns we can discern that appear applicable to most tissues and species. During the postnatal period, there is rapid synthesis of matrix molecules, some of which are destined for turnover and replacement, whereas others enter the pool of insoluble matrix, where they remain throughout the animal's life. Enzymatic cross-linking serves as the dominant influence during the first part of the life span, stabilizing and shaping the matrix such that its characteristic properties will best serve the functional needs of the tissue in which it inheres. In middle age, however, the matrix comes increasingly under the sway of stochastic forces that inexorably twist it in unpredictable ways that no longer adhere to the rules of biological design. Recently, the contributions of glycation and oxidation to this process have been the focus of particular interest, and agents designed to intervene in these reactions are being developed. However, perhaps because of the inherent complexity of the process, successful strategies available for attenuating these changes in matrix have not yet been developed. We evidently have much to learn about the intricate mechanisms of this strange clock that keeps unseen time beneath our skin.

See also: Diet and Nutrition; Glycation.

Further Reading

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Falls

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Glossary

Environmental Assessment and Modification – A fall prevention strategy that identifies and removes potential hazards.

Extrinsic Risk Factors – External or environmental risk factors.

Fall – Event resulting in a person inadvertently coming to rest on the ground or another lower level.

Intrinsic Risk Factors – Risk factors arising from inside the body.

Risk Factor – A characteristic found significantly more often in individuals who subsequently experience a certain adverse event.

Introduction

A fall is defined as an event resulting in a person inadvertently coming to rest on the ground or another lower level. Falls are typically associated with tripping or slipping; however, in older persons falls have multiple precipitating causes and predisposing risk factors. A fall may be the first indicator of an acute medical problem (infection, postural hypotension, cardiac arrhythmia), may indicate progression of a chronic disease (parkinsonism, dementia, diabetic neuropathy), or simply may be a marker for the onset of normal age-related changes in vision, gait, and strength. Moreover, most falls experienced by older persons have multifactorial and interacting causes (e.g., a trip over an electrical cord contributed to by both a gait disorder and poor vision).

Epidemiology of Falls

Incidence of Falls

Prospective studies have reported that 30 to 60% of community-dwelling older adults fall each year, with about half of fallers experiencing multiple falls. Fall incidence rates for community-dwelling older populations range from 0.2 to 1.6 falls per person per year, with a mean of about 0.7 falls per year. Incidence rises steadily after middle age and tends to be highest among individuals 80 years and older. These incidence rates are based on self-reported data, which may underestimate the true incidence of falls.

Incidence rates in institutionalized elderly populations are generally higher than in community-living elderly populations. This difference is due both to the older age and frailer nature of institutionalized populations and to the more accurate reporting of falls in institutional settings. In surveys of nursing home populations, the percentage of residents who fall each year ranges from 16 to 75%, with an overall mean of 43%. Annual incidence of falls in long-term care facilities averages about 1.6 falls per occupied bed (range from 0.2 to 3.6 falls). Incidence rates from hospital-based surveys are somewhat lower, with a mean of 1.4 falls per bed annually (range from 0.5 to 2.7 falls). This variation in incidence rates between the institutionalized populations most likely reflects differences in case mix, ambulation levels, reporting practices, and institutional fall prevention policies and programs.

Fall-Related Mortality

Accidents are the fifth leading cause of death in older adults (after cardiovascular, cancer, stroke, and pulmonary causes), and falls constitute two-thirds of these accidental deaths. About three-fourths of deaths due to falls in the United States occur in the 13% of the population aged 65 and older. Fall-related mortality increases dramatically with advancing age, especially in populations over 70. Older men have a higher mortality rate from falls than older women, and nursing home residents 85 years and older account for one out of five fatal falls. The estimated

1% of fallers who sustain a hip fracture have a 20 to 30% mortality rate within 1 year of the fracture.

Fall-Related Morbidity

A key issue of concern is not simply the high incidence of falls in elderly persons, since young children and athletes have an even higher incidence of falls, but rather the combination of a high incidence and a high susceptibility to injury. This propensity for fall-related injury in elderly persons is due to a high prevalence of clinical diseases (e.g., osteoporosis) and age-related physiological changes (e.g., slowed protective reflexes) that make even a relatively mild fall particularly dangerous. While most falls produce no serious injury, community surveys have reported that over half of falls result in at least minor injuries, and between 5 and 10% of community-dwelling older persons who fall each year sustain a serious injury, such as a fracture, head injury, or serious laceration. The proportion of reported falls that result in serious injuries is similar in community-dwelling and institutionalized populations, but the range is wide (1–39%) because of differences in reporting practices. These injuries are often associated with considerable long-term morbidity. Among community-dwelling fallers with hip fractures, studies have shown that between 25 and 75% do not recover their prefracture level of function in ambulation or activities of daily living.

In addition to physical injuries, falls can produce other serious consequences for the elderly person. Repeated falls are a common reason for the admission of previously independent elderly persons to long-term care institutions. Fear of falling has also been recognized as a negative consequence of falls. Surveys have reported that between 30 and 73% of older persons who have fallen acknowledge a fear of falling. This post-fall anxiety syndrome can result in self-imposed activity restrictions among both home-living and institutionalized elderly fallers. Loss of confidence in the ability to ambulate safely can result in further functional decline, depression, feelings of helplessness, and social isolation.

Risk Factors for Falls

Intrinsic Risk Factors

A risk factor is a characteristic found significantly more often in individuals who subsequently experience a certain adverse event than in individuals not experiencing the event. Intrinsic risk factors (risk factors arising from inside the body) can include age-related changes as well as acute or chronic diseases. The most commonly reported risk factors from case-control studies conducted in community-living and institutionalized populations are listed in **Table 1**, along with the mean relative risk of falls for persons with each risk factor. It should be noted that some of these are directly involved in causing falls (e.g., weakness, gait and balance disorder), while others may be markers for contributing factors (e.g., prior falls, assistive device, age $>$ 80).

Among these studies, lower extremity weakness (detected by either functional testing or manual muscle examination) was identified as the most potent risk factor associated with falls, increasing the odds of falling, on average, over four times (4.4, range from 1.5 to 10.3). Not only potent, leg weakness is also very common in older persons. As a whole, healthy older people score 20 to 40% lower on strength tests than young adults, and the prevalence of detectable lower extremity weakness ranges from 57% among residents of an intermediate-care facility to over 80% among residents of a skilled nursing

Table 1 Risk factors for falls identified in 16 studies[a] examining multiple risk factors: results of univariate analysis

Risk factor	*Significant/total*[b]	*Mean RR-OR*[c]	*Range*
Lower extremity weakness	10/11	4.4	1.5–10.3
History of falls	12/13	3.0	1.7–7.0
Gait deficit	10/12	2.9	1.3–5.6
Balance deficit	8/11	2.9	1.6–5.4
Use assistive device	8/8	2.6	1.2–4.6
Visual deficit	6/12	2.5	1.6–3.5
Arthritis	3/7	2.4	1.9–2.9
Impaired ADL	8/9	2.3	1.5–3.1
Depression	3/6	2.2	1.7–2.5
Cognitive impairment	4/11	1.8	1.0–2.3
Age $>$ 80 years	5/8	1.7	1.1–2.5

[a] Data from Rubenstein and Josephson (2001).
[b] Number of studies with significant odds ratio or relative risk ratio in univariate analysis per total number of studies that included each factor.
[c] Relative risk ratios (RR) calculated for prospective studies. Odds ratios (OD) calculated for retrospective studies.

facility. Weakness often stems from deconditioning due to limited physical activity or prolonged bed rest, together with chronic debilitating medical conditions, such as heart failure, stroke, or pulmonary disease.

Individuals who have already fallen have a threefold risk of falling again within 1 year. While recurrent falls in an individual are frequently due to the same underlying cause (e.g., gait disorder, orthostatic hypotension), they can also be an indication of disease progression (e.g., parkinsonism, dementia) or a new acute problem (e.g., infection, dehydration).

Gait and balance disorders are also common among older adults, affecting between 20 and 50% of people over the age of 65 years. Among nursing home populations, nearly three-fourths of residents require assistance with ambulation or are unable to ambulate. Both gait and balance impairments were found to be a significant risk factor for falls, associated with about a 3-fold increased risk of falling, and use of an assistive device for ambulation was associated with a 2.6-fold increased risk of falling.

Visual impairment has been found to increase the risk of falling about 2.5 times. About 18% of noninstitutionalized persons 70 years and older have substantial visual impairment. The primary causes, most of which are treatable, include cataracts, glaucoma, and macular degeneration.

Arthritis, the most common chronic condition affecting persons 70 years and older in the United States, increases the risk of falling about 2.4 times. The relationship between arthritis and falls is most likely related to the gait impairment and weakness that are often associated with arthritis.

Functional impairment, usually indicated by inability to perform basic activities of daily living (ADLs) (e.g., dressing, bathing, feeding oneself), has been shown to double the risk for falling. In the community, ADL impairment affects 20% of persons over age 70. In the nursing home setting, the prevalence of functional impairment is higher, with 96% of nursing home residents requiring assistance with bathing and 45% requiring assistance with eating.

Cognitive impairment and depression have both been identified as independent risk factors for falling, associated with about a twofold increased risk of falling. Confusion and cognitive impairment are frequently cited causes of falls and may reflect an underlying systemic or metabolic process (e.g., electrolyte imbalance, fever). Dementia can increase falls by impairing judgment, visuospatial perception, and orientation ability. Falls also occur when demented residents wander, attempt to get out of wheelchairs, or climb over bed side rails. Cognitive impairment affects between 5 and 15% of persons over age 65, and the prevalence rises with age and among institutionalized populations.

The risk of falls has also been shown to nearly double for individuals over the age of 80. This is probably due to the rising prevalence of multiple risk factors associated with age.

The relationship between medication use and falls has also been examined in many studies. A recent meta-analysis found a significantly increased risk from psychotropic medication, class 1a antiarrhythmic medications, digoxin, and diuretics. Several studies also have shown strong relationships between use of multiple medications and risk of falls.

Additional risk factors associated particularly with falls likely to cause injury include being female, having low body mass (both probably largely related to osteoporosis), and having higher activity levels.

Studies have also shown that the risk of falling increases dramatically as the number of risk factors increases. In a study by Robbins, involving both an institutionalized and outpatient population, many risk factors were individually significantly related to falls. Multivariate analysis enabled simplification of the model so that maximum predictive accuracy could be obtained by using only three risk factors (i.e., hip weakness assessed manually, unstable balance, and taking four or more prescribed medications) in a branching logic, algorithmic fashion. With this model the predicted 1 year risk of falling ranged from 12% for persons with none of the three risk factors to 100% for persons with all three risk factors.

Extrinsic Risk Factors

Extrinsic risk factors for falls include environmental factors, footwear, and restraints. So-called accidental falls, or falls stemming from environmental hazards, are common in both home and institutional settings. However, most falls in this category stem from interactions between environmental hazards or hazardous activities and increased individual susceptibility to hazards from intrinsic risk factors. Although the environment outside the home certainly contains many fall hazards, impaired older adults are most likely to fall inside their own homes – perhaps because they spend more time inside and may be more careless there. These in-home falls generally occur on a level surface during activities that require only low to moderate displacement of the individual's center of gravity (i.e., standing, walking, transferring, bending, or reaching). Within nursing homes, most falls occur in the bedroom at the bedside or in the bathroom. Certain activities commonly associated with falls in these locations include arising from bed, ambulating to and from the bathroom, and transferring to a bed,

chair, or toilet –activities known to be associated with intrinsic fall risks from postural changes and vasovagal reflexes. Environmental hazards that frequently contribute to these falls include wet floors (due to spills or episodes of incontinence), poor lighting, bedrails, and improper bed height. Falls have also been reported to increase when nurse staffing is low and during shift changes, presumably due to lack of supervision, and following meals, likely related to the phenomenon of postprandial orthostatic hypotension.

Footwear is an important, but commonly unrecognized, risk factor for falls. Ill-fitting shoes (e.g., too tight or too loose), shoes with high or narrow heels, or shoes with worn soles can all alter gait and balance and subsequently increase fall risk. Shoes that are left untied can contribute to trips. Leather soles can contribute to slips. In addition, not wearing shoes (e.g., going barefoot or wearing socks) has been shown to significantly increase fall risk. Footwear should fit properly, be low heeled, and have a non-slippery sole.

Another environmental factor that can contribute to fall risk is the use of physical restraints, such as soft restraining vests and bedrails. For many years physical restraints were commonly used to prevent falls in nursing homes and hospitals. However, evidence has shown that physical restraints may actually contribute to falls, injuries, and mortality in certain instances when patients attempt to climb over bedrails, or when they untie or slip out of soft restraints. By limiting mobility, restraints also can contribute to weakness, gait and balance impairment, and confusion, thereby further increasing fall risk. There has been a move away from the use of physical restraints, and it is now generally recognized that the adverse effects on functional status and quality of life outweigh any potential benefit in preventing falls.

Fall Prevention Strategies

Multidimensional Fall Risk Assessment

Recent guidelines on fall prevention and treatment have been published by the American and British Geriatrics Societies after careful review of extensive published evidence. The purpose of these guidelines is to assist clinicians in the assessment of fall risk and the management of older patients who are at risk of falling and who have fallen. The guidelines recommend that a fall risk assessment should be an integral part of primary health care for older persons. However, the intensity of the assessment will vary with the target population. For low-risk community-dwelling populations, the guidelines recommend that all older patients should be asked at least once a year about falls. Older persons who report a single fall should be observed for mobility impairment and unsteadiness using a simple observational test. Those patients who demonstrate mobility problems or unsteadiness should be referred for further assessment. High-risk populations (e.g., older persons who seek medical attention because of a fall, report multiple falls in the past year, have abnormalities of gait and/or balance, or reside in a nursing home) should have a more comprehensive and detailed assessment.

The goals of the detailed multidimensional fall risk assessment are twofold: (1) to diagnose and treat patients after a fall and (2) to identify risk factors for future falls and implement appropriate interventions. Most of these risk factors can be easily assessed in the physician's office using basic examination techniques or standardized instruments (**Table 2**). The fall assessment should incorporate the basic principles of comprehensive geriatric assessment, namely, a multidimensional assessment to quantify medical, psychosocial, and functional capabilities and problems in order to develop a comprehensive plan for therapy.

The multidimensional fall risk assessment includes the following: a history of fall circumstances and medical problems; review of medications; mobility assessment; an examination of vision, gait and balance, and lower extremity joint function; a basic neurological examination, including muscle strength and mental status; and assessment of cardiovascular status. Other components of the fall risk assessment can include functional performance tests and an environmental assessment of the individual's living location.

Optimally, the multidimensional fall assessment will uncover direct causes and/or contributing risk factors amenable to medical therapy or other corrective interventions. Because of the multifactorial nature of falls, there is no standard approach to treatment or prevention. In cases where the cause of a fall is due to an obvious acute problem, treatment may be relatively simple, direct, and effective (e.g., discontinuing medication that causes postural hypotension, cataract surgery). However, patients with multiple risk factors will often require a combination of medical, rehabilitative, environmental, and/or behavioral intervention strategies (e.g., treating syncope, removing environmental hazards, prescribing strengthening exercises, and supplying a properly fitted cane).

Exercise Interventions

Numerous studies have shown that exercise can improve important fall risk factors such as muscle

Table 2 Clinical approaches to specific causes or common risk factors discovered in the fall assessment

Cause/risk factor	*Evaluation*	*Therapeutic measure*
Weakness		
	• Review medical problems and medications • Complete neurological examination (quantify severity; identify central deficits, neuropathies, myopathies) • Physical therapy (PT) evaluation for therapeutic recommendations	• Treat reversible causes • Exercise regimen • Prescribe appropriate assistive devices
Gait/balance deficit		
	• Neurological examination (including gait analysis) • PT evaluation for therapeutic recommendations • Orthopedic, foot and footwear evaluation	• Treat reversible causes • Gait and/or balance training • Prescribe assistive device
Visual deficit		
	• Vision examination	• Corrective lenses, surgery, low-vision aids, and/or environmental adaptation
Environmental hazards		
	• Environmental assessment (home visit or self-completed checklist)	• Remove hazards • Adaptive aids
Postural hypotension		
	• Review medical problems and medications (rule out infection, dehydration, autonomic dysfunction, anemia, drug effect)	• Correct treatable problems (medication, dehydration, infection) • Teach adaptive behavior (slow rising, raised head of bed)
Confusion/delirium		
	• Dementia/delirium evaluation (quantify severity; identify toxic/metabolic problem, rule out structural lesion) • Functional evaluation	• Treat reversible problem • Environmental safety adaptations
Syncope/arrhythmia		
	• Full syncope evaluation (rule out cardiac arrhythmia, valvular deficit, metabolic abnormality)	• Treat underlying problem
Dizziness/vertigo		
	• Medical evaluation and medication review • Neurological evaluation • Vestibular evaluation	• Treat underlying problem • Prescribe exercises for benign postural vertigo, if appropriate

weakness, poor balance, and gait impairment in both healthy and impaired older adults. Subsequently, exercise has become a widely studied fall prevention intervention. Different exercise models have been evaluated, including exercise groups and individualized home programs, among healthy and impaired populations.

Group exercise programs designed as fall prevention interventions typically are held two to three times per week for about an hour and are supervised by a physical therapist or trained exercise instructor. Most group programs include a combination of exercises to improve flexibility, strength, and balance, and some level of aerobic conditioning. Progressive strength training generally focuses on lower and upper extremity large muscle groups and may use body weight, ankle weights, weight machines, or elastic bands for resistance. Balance training often includes a range of static and dynamic exercises (e.g., standing on one foot, tandem stand, ball games, movement to music) and functional activities (e.g., reaching, bending, transferring). To improve aerobic conditioning, exercise programs have used whole body exercises, walking and stair climbing, and stationary bicycles. Although performed in a group setting, exercises are usually individualized to the participant's abilities.

Home exercise programs are structured so that participants learn the exercises from a trained exercise professional during a home visit or group session and then perform the exercises unsupervised in their homes. Home exercise programs typically include the same types of exercises as the group programs, only fewer and often at a lower intensity. Home exercise programs also frequently incorporate a walking program.

Tai chi is another type of exercise that has been studied as a means of improving balance and reducing risk of falling. Tai chi consists of a series of slow, rhythmic movements that require trunk rotation, dynamic weight shifting, and coordination between upper and lower extremity movements. Tai chi has been studied in group and home programs.

Environmental Assessment and Modification

Environmental assessment and modification is another promising fall prevention strategy, used as a means of identifying and removing potential hazards (e.g., clutter, poor lighting, throw rugs) and for modifying the environment to improve mobility and safety (e.g., installation of grab bars, raised toilet seats, lowered bed height). A number of self-administered home safety checklists, designed for use by older people in their homes, assist in identifying important hazards and offer suggestions for improving safety. These checklists are most appropriate for use with average risk and cognitively intact older adults.

For higher-risk populations, in-home environmental assessment by a nurse or occupational therapist provides an opportunity for the health-care professional to observe how an older person functions within the home, which may help identify safety problems that would not necessarily be identified with a self-administered checklist or interview.

In institutional settings, environmental safety policies and practices are generally in place to protect both patients and staff. Important safety issues for hospitals and nursing homes include adequate lighting and handrails in hallways, close monitoring for spilled liquids on the floors, unobstructed walkways, appropriate assistive devices in bathrooms (e.g., grab bars, shower chairs, raised toilet seats), furniture that is easy to rise from, and proper bed height.

Multifactorial Interventions

Multifactorial interventions are those that combine several fall prevention strategies into a coordinated program. Generally multifactorial interventions include some degree of fall risk assessment, followed by one or more risk factor modification strategies, such as exercise, education, and/or environmental modification.

Institutional Interventions

In institutional settings, fall risk assessment tools are commonly used to identify those who are at greatest risk for sustaining a fall or fall-related injury and to isolate specific risk factors that are amenable to intervention. There are many published assessment tools that are used to help health professions better target limited resources to those who would benefit most from preventive interventions. These instruments typically rank a person's risk for falling as high, medium, or low based on the presence or absence of such risk factors as cognitive impairment, mobility dysfunction, incontinence, acute/chronic illnesses, sensory deficits, medication use, and history of falling. The tools may or may not include physical assessments in addition to responses to questions that rely on self-report. Most screening tools are brief, are generally administered by a nurse on admission to hospital or a nursing home, and are usually updated on a regular basis or when there is a change in health status. Once a patient has been identified as being at high risk for falling, a nursing care plan is usually developed that includes interventions aimed at injury prevention. Such interventions can include indicating on the medical chart and the patient's door that the patient is at high risk for falls, moving high-risk patients to rooms that are close to the nursing station to increase observation, periodic reassessment of patients following new episodes of illness or change in medication, lowering side rails and bed height for patients who climb out of bed, increasing nurse-to-patient ratio, and fall prevention education for patients and staff.

Other promising strategies aimed at reducing falls and fall-related injuries in nursing homes include the use of vitamin D and calcium supplements to enhance bone and muscle strength and the use of special hip protectors (worn in undergarments shielding the greater trochanter of the hip) to prevent hip fractures due to falling.

Effectiveness of Fall Prevention Strategies

Prevention of falls and fall-related injuries is an important challenge for clinicians and researchers. The heightened interest in identifying effective fall prevention strategies has resulted in the publication of numerous randomized controlled trials. These intervention trials have been targeted to many different populations and have included a wide range of strategies. Study populations have included healthy older adults; individuals at risk for falling; community-living, hospitalized, and institutionalized populations; as well as caregivers and the home or institutional environment. Many different intervention strategies have been evaluated, often unique to the study site, and there is great variation in duration and intensity of the intervention, outcome measurements, and length of follow-up. This diversity in the published literature has made it difficult to determine which type of intervention is most effective for

preventing falls, and which target group of older adults will benefit most from which type of intervention. Fortunately, meta-analyses of randomized controlled trials have been able to summarize data from these studies and even assess the relative effectiveness of specific types of fall prevention interventions.

The results of a recent meta-analysis by Chang et al. indicate that multidimensional risk assessment combined with interventions directed toward reducing these risks was the most effective fall prevention strategy. When analyzed as a group, interventions using multidimensional risk assessment and risk reduction lowered the risk of falling by 18% and reduced the average number of falls by 43%.

The next most effective single intervention identified in this meta-analysis was exercise intended to improve balance, strength, flexibility, and/or endurance. Overall, exercise interventions reduced the risk of falls by 12% and the mean number of falls by 19%. Exercise was effective in reducing falls when used alone and when included as part of a multifactorial intervention. Types of exercise that have been found to be effective include tai chi and programs that combined balance and strength training.

While studies did not demonstrate that home modification alone will reduce falls, a number of multifactorial interventions that included home modification were effective, particularly among individuals who had a history of previous falls.

Individual intervention trials that have been most effective in reducing fall rates have involved multifactorial intervention programs, which is consistent with the concept that falls are usually the result of interactions between multiple intrinsic and extrinsic risk factors. Effective interventions generally have included risk assessment, tailored exercise or physical therapy to improve gait, balance, and strength, medication review and modification, and other elements such as education about fall risk factors, referrals to health-care providers for treatment of chronic conditions that may contribute to fall risk, and having vision assessed and corrected.

A meta-analysis based on five randomized controlled trials reported that vitamin D supplementation appears to reduce the risk of falls by more than 20% among ambulatory or institutionalized older adults. The hypothesized mechanism is from a direct beneficial effect of vitamin D on neuromuscular function. However, the studies did not measure vitamin D levels at baseline, so it is not clear whether this apparent benefit stemmed from treating a deficiency or from a pharmacological effect of the vitamin D in non-deficient individuals.

While hip protectors appear to be effective in preventing hip fracture in nursing home settings, their effect in community populations has not yet been demonstrated. This is likely because of poor patient compliance rates in the community. A meta-analysis based on six randomized trials concluded that hip protectors appear to reduce risk of hip fracture in selected high-risk populations where compliance can be closely monitored.

See also: Balance, Posture and Gait; Frail Elderly; Disability, Functional Status and Activities of Daily Living.

Further Reading

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Frail Elderly

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Glossary

Comorbidity – The presence of coexisting diseases, which are clinically manifest yet unrelated.

Disability – Having difficulty in performing or being unable to perform basic and important tasks usually required for independent living, or activities of daily living (ADL; mobility, transfers, dressing, toileting, bathing, and eating), or instrumental ADL (IADL; shopping, transportation, home chores, money management, making appointments, taking medicines, and handling emergencies).

Resilience – This concept was originally applied to children and denotes the maintenance of normal development despite threats or risks due to nonnormative influences as well as the ability to recover from trauma. Resilience also includes the positive pole of individual differences in people's responses to stress and adversity. In elderly populations, resilience refers to the capacity to prepare for transitions or prevent life accidents, and, in case of problems, to restore and/or compensate for affected resources by activating other underused, existing resources.

Senescence – The biological process of growing old, associated with an increased vulnerability to stress, a susceptibility to disease, and the probability of dying. It is associated with the period in a person's life when physiological degenerative processes overtake regenerative processes.

Introduction

Frail elders are at high risk for adverse outcomes (falls, hospitalization, institutionalization, disability, death). They exhibit vulnerability to medical, psychosocial, or environmental stressors and are unable to regain equilibrium with the surrounding environment after a disturbing event such as a fall, an acute illness, or an emotional upheaval. Frailty is conceptualized as a multisystem reduction in reserve capacity. There is no current consensus on the measure of frailty; according to the adopted criteria and the characteristics of the sample population, the prevalence of frail elders (65+) varies from 7 to 25%. Although frailty is not confined to older adults, it increases with age. Frailty is more common in women and in those at the greatest social disadvantage.

Conceptualizations and Definitions of Frailty

Development of the Concept and Operationalization of Frailty

The concept of frail elder was hardly ever used before the 1980s. Until then, other terms with a strong physical and medical connotation were used, mainly to describe older individuals who were in need of assistance or who were disabled. These terms included the chronic sick, the disabled, and the incapacitated. In the late 1980s and especially in the 1990s, the concept of frailty became popular in the medical literature, and the number of its citations increased exponentially. This increase in use was due to the first attempts at an explicit definition of frailty. The first definitions were strongly medical in nature, underscoring the health-related problems of affected individuals. Frail elders were vulnerable to various stressors, subject to physical or mental problems of aging, unable to attend to their basic needs, required institutional care, and generally were dependent on others for sufficient daily functioning. In short, frailty became a close relative of disability in older individuals.

This definition originated largely from the geriatric community, and, accordingly, it was associated with general physical and mental health consequences on the individual level. Indeed, the geriatric community soon realized that one outcome of the remarkable increase in life expectancy was the increasing number of older individuals affected by similar conditions. The end expression of these developments was the need for information about older individuals who cannot be classified as aging successfully.

The necessity for knowledge fueled further research that attempted to address what the causes and symptoms of frailty were. The definitions of frailty were rather specific, focusing on basic components or mechanisms – mainly of a medical nature – thought to specifically define and describe the properties of frail elders. The first attempts to screen for frail elders were based on the limited measures of their capacity to function independently. In this line of research, only mobility and motor performance were assessed, with the additional objective of identifying inexpensive markers of frailty. These

definitions were based mostly on objective criteria assessed by geriatricians or medical doctors, hence concentrating all efforts on hospitalized and nursing home populations.

It soon became evident that highly specific characterizations of frailty were too limiting in scope and generally unsatisfactory for the purpose of further understanding and prevention. Multisystem definitions that considered various biomedical aspects of frailty and that were not limited to single indicators emerged and relied on the belief that concurrent impairments in several biological systems would lead to frailty. Frailty was described as a constellation of signs and symptoms rather than as a discrete clinical entity – to the point that it resisted a precise scientific meaning. In this context, the notions of vulnerability, loss of resilience, alteration in homeostasis, and decreased reserves were frequently employed to discuss frailty. Indeed, it was generally agreed that frailty was a state of high vulnerability and could lead to adverse health outcomes such as dependence, falls, need for long-term care, and death.

Frailty was also associated with a loss of resilience that affects the individual's capacity to maintain or recover from loss in order to regain equilibrium with the surrounding environment and with altered homeostatic responses to stress. Frailty could hence be defined as a syndrome of decreased reserve and resistance to stressors, resulting from cumulative decline across multiple physiological systems. Most of the conceptualizations of frailty are consistent regarding the loss of reserve beyond a given threshold. Accordingly, the capacity for older persons to withstand physical and emotional stressors or recover from acute illnesses depends on their reserve capacity. Disease in this regard is not a necessary condition of frailty, and often frail older adults may experience declines in physiological functioning in the absence of morbidity. However, frailty, with its associated decrease of resources, is certainly related to a higher risk of disease. Indeed, physiological reserves, whose decrements are inevitable with aging and are accelerated by diseases and an inadequate lifestyle (e.g., physical inactivity, heavy alcohol consumption, smoking, nutritional problems, social isolation), may reach a lower threshold limit below which an individual would be considered frail.

At the same time, biomedical definitions of frailty that integrated the notion of multisystem reduction in reserve capacity were proposed. These definitions posited that decrements in musculoskeletal functioning, aerobic capacity, cognitive functions, nutritional status, and neuroendocrine and immune system functions must be present to constitute frailty. Hence, various markers of frailty were recommended in relation to general physiological functioning relevant to everyday activities. Examples include low body mass index; loss of strength, endurance, and balance; slow gait speed; and low activity and energy. In particular, the loss of muscle mass and diminished muscle function (sarcopenia, literally melting flesh) has been suggested as a major cause of frailty. These markers, however, are not directly treatable because they are indicative of larger processes.

A parallel research agenda attempted to identify biological and physiological determinants and precursors of frailty at the incipient phase of the process – before clinical symptoms of frailty manifested themselves. At this level of conceptualization, frailty crosses biological theories of senescence, which may conceive of frailty as a consequence of free radicals, caloric restrictions, and hormonal levels, and stress theories of aging, positing that frailty mechanisms interact with changes in the hypothalamic–pituitary–adrenocortical axis (thereby affecting the way the cerebral cortex appraises the stressor and consequently how the hypothalamus stimulates the pituitary and adrenal glands, which are two basic components of the endocrine system that, with the nervous system, control bodily activities). From this perspective, sex differences in frailty prevalence may be interpreted as the consequence of sex differences in neuroendocrine reactivity, which is due to the postmenopausal increase in cortisol secretion in women who are not undergoing hormonal replacement therapy.

Empirical investigations focused on cytokine overexpression and hormonal decline, which reflect an altered homeostatic response to stressors. Evidence emerged of links between physiological markers and the major symptoms of frailty. For example, a dysregulation of cytokine formation can lead to loss of muscle strength, and leptin (a hormonal mediator) acts to reduce food intake and increase energy expenditure. While this line of research aims to stimulate new therapeutic interventions and promote primary prevention, it remains unclear whether these markers reflect aging itself or frailty.

More comprehensive, multidimensional conceptualizations of frailty consider the complex interplay of biological, physiological, physical, psychological, social, and environmental factors. Some authors believe that beyond physical frailty, mental, emotional, or social forms of frailty exist, or at least that frailty operates on not just a person's health, but also a person's psychological and social life dimensions. In particular, frailty may originate from or be exacerbated by specific conditions in the environment. These more recent conceptualizations necessarily consider subjective reports based on the direct

experience of older individuals, recognizing not only the reality of physical and biological conditions, but also how these conditions affect the individual. Community-dwelling populations are therefore often used when studying frailty, which reduces the risks of limited findings owing to sample selectivity regarding late-stage frail elders.

From this perspective, frailty becomes an object of investigation in psychological theories of aging. For instance, the theory of selection, optimization, and compensation (SOC) presupposes that to develop successfully (by maximizing gains and minimizing losses) individuals ought to coordinate the following: (1) the selection of and commitment to developmental trajectories with (2) the optimization of gains in resources of functioning levels and (3) the compensation in order to maintain the resources of functioning levels in the presence of losses. Proper application of the strategies suggested by SOC may delay the onset of frailty by ameliorating one's support (or resources) received from the surrounding cultural context. According to this approach, assessment and prevention strategies should not focus exclusively on the health of frail elders but should also consider their environment.

Theories of everyday competence attempt to explain how aging individuals function effectively in a given physical and social context by applying fundamental processes (e.g., cognitive resources) to relevant daily tasks. Here again frailty can be conceived as an improper balance between one's cognitive and psychological resources on the one hand and the available contextual resources on the other. How one copes and lives with frailty given one's means – as well as the resources of the surrounding environment rather than frailty itself – became of primary interest to some scholars.

The importance of the dynamic (and often systemic) interplay between older individuals and their environment may help to further explain the process of frailty. Frailty may be considered the result of older people dissociating themselves from their environment, resulting in role changes marked by a loss of autonomy that is often associated with interventions of the informal network (spouse, family, friends) and professional actors or institutions (home care, medical or social institutions, nursing homes, etc.). From this perspective, the emergence of frailty corresponds to the process described in the revised version of the theory of disengagement. According to this theory, the aging process is understood as an individual's forced or anticipated process of selection of activities and relationships. Frailty may be conceptualized as a normative aging process, which results in a selection of activities and relationships that work to maintain a certain level of well-being and continuity in the most meaningful spheres of life.

This broad approach has caused the number of fields studying frailty to expand, including the cognitive, emotional, social, and spiritual domains of life. Consequently, more recent empirical evidence on frailty has focused on, among others, sex differences that are not biological in nature, the quantitative and qualitative effects that frailty exerts on one's friendships, the preventive effect of psychological characteristics (such as positive affect on the advancement and treatment of frailty, and the precipitating effect that the fear of falling, rather than the act of falling itself, plays on the development of frailty), and the dangers of mistaking frailty and depression. Consequently, the exponential increase in frailty citations in the medical literature was paralleled, to a small degree, by analogous increases in the psychological and sociological literature. Frailty was no longer just a medical issue.

Related yet Distinct Concepts

For years frailty has been practically synonymous with disability and old age. General recognition of wide individual differences between old and very old age as well as in the development, presence, and significance of disabilities quickly challenged the simplistic equations that frailty equalled ADL or IADL disability and frailty equalled old age. Since then, it has been shown that disability is a probable outcome of frailty. This confirms the significance of frailty's predictive status in community-based populations, in which people are still relatively functional. An attempt was made to ameliorate the prediction of chronological age with respect to frailty by constructing an index of a person's biological age, which was defined as the total number of deficits that are quite different in nature. Although superior in prediction than chronological age, the biological age frailty predictor correlated very highly with its chronological counterpart and further was lacking in overall substantive meaning and therefore prevention utility.

Comorbidity has been linked to frailty all too often. Co-occurrence of frailty and comorbidity is indeed frequent. While comorbid diseases may contribute to the development of frailty, the presence of frailty may contribute to the development or progression of diseases. However, frailty can occur independently of comorbidity. For instance, some older adults experience symptoms such as sarcopenia and compromised immune functioning in the absence of morbidity.

Older patients diagnosed with psychological depression, which is assessed according to standard

psychological and psychiatric criteria for classifying mental disorders (e.g., DSM-IV-TR or ICD-10), may be at a higher risk for developing frailty or for not being able to cope, adapt, and develop resilience strategies to overcome frailty. Moreover, exhaustion, weight loss, and slowing and decreased activities have been recognized as characteristics of psychological depression and are at the same time included in definitions of frailty. Although depression and frailty are quite different, misdiagnoses may be frequent and parallels do exist. Either condition can be classified as a cause, consequence, or comorbidity of the other.

Models of the Development and Outcomes of Frailty

There are different types of models that describe frailty as a stage or a transition phase in the process of aging. The following sections focus on two distinct, but not exclusive, ways of describing this process: linear models of frailty and the cyclical model of frailty.

Linear Models of Frailty

One of the most diffused models of frailty is the linear model. This model has many variants, but most descriptions appear to rely on a former model: the model of the disablement process. This model describes a more or less irreversible declining process that starts from autonomy and can evolve toward impairment. This can then transform into a disability, to finally end in death. A handicap or a disability is then considered in many health-care systems to be the main criterion for an older person to be eligible for adequate treatment and follow-up. This well-known and influential model (one that is still dominant in gerontology among many researchers and practitioners and in institutions such as the World Health Organization) has influenced many descriptions of the process of frailty.

The linear model is usually deterministic because it assumes something like a causal and unidirectional chain from autonomy or independence to disability and dependence – associated in most cases with an increase in age. This position can also be found in models in which frailty represents an important intermediate stage between two extreme poles: autonomy and death (see **Figure 1**). It is important to note that in most of these models, frailty is not an all-or-nothing phenomenon, and different degrees of frailty are described (for example, frailty scales ranging from mild to severe). These degrees of frailty correspond to a series of episodic, progressive, and often irreversible losses. Frailty in some linear models includes a wide range of health and vitality states, which can be found in old and very old age, and between the states of autonomy, independence, vitality, and, finally, death. The process of frailty often corresponds to an accumulation of functional losses that progressively erodes the capacities of older people to perform diverse activities, resulting in an increasing need for help and care.

Another common characteristic of the linear model is its focus on the associated or causal antecedents of frailty as well as its outcomes. Studies describe a large number of possible factors that may explain frailty or that may even result from frailty. However, a main contribution of the linear

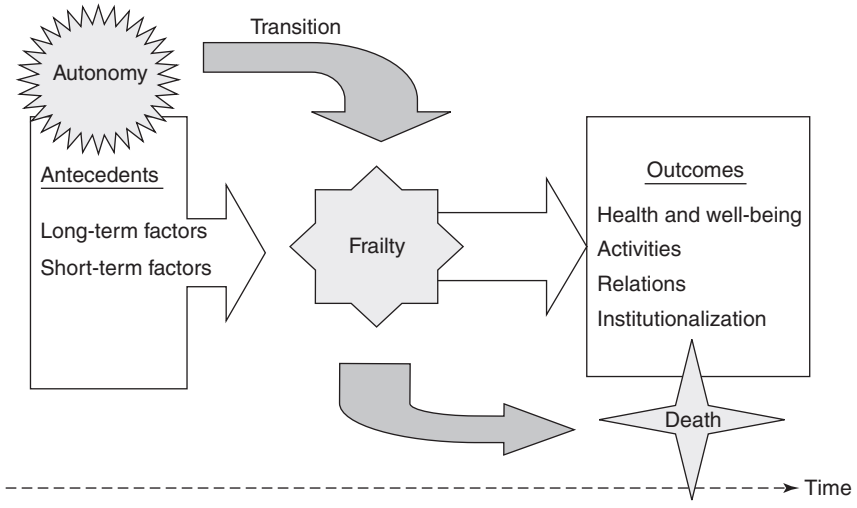

Figure 1 The linear model of frailty as an intermediate stage between autonomy and death: the impact of long- and short-term factors on frailty with its consequences on health and well-being, activities, relations, and institutionalization.

model is the identification of long-term and short-term factors.

Consistent with a life course perspective, diverse long-term biographic antecedents of frailty were identified. These may be related to biological or genetic resources as well as to long-term effects of physical (wear and tear associated with different behaviors, activities, or professional occupations) and social exposures (i.e., individuals in disadvantaged social positions are relatively more exposed to risks and threats of a different nature than those in more privileged ones). These risk factors may be related to the individual but may also be considered at the collective level, as some events such as epidemics, wars, economic depression, and cultural changes have had an important impact on the life trajectories of many members of whole birth cohorts.

This lifelong accumulation of damage is expressed in the concept of the allostatic load. An allostatic load and the repetitive exposure to various types of stress may wear down individual resistance. However, one must not infer that stress necessarily causes a long-term negative outcome for the elderly; mild stressors (e.g., caloric restrictions, exposure to cold temperatures) have been found to increase longevity in studies using animal models. Mild stressors may induce adaptive reactions and thus reinforce defenses and coping strategies.

On a short-term basis, frailty may also be explained by a large number of different biomedical and psychosocial factors, which range from micro-level factors such as molecules to macro-level social factors such as social class. These factors include past negative or declining health status (illness, strokes, chronic diseases such as diabetes or Parkinson's disease, a decrease in functional health, depression, dementia, poor dentition, weight loss, etc.), disruptive or traumatic events (falls, a death in the family, hospitalization, etc.), and various social factors (being a woman, social isolation, poor finances, etc.).

Other factors that are described as antecedents, mediators, or moderators include psychosocial adaptations to endogenous or exogenous stresses. These latter models have developed within the life span and social psychology traditions. They include the general processes of adaptation and self-regulation, such as the SOC model, primary control strategies (behavior–event contingencies achieved by an individual: the investment of time and effort, the recruitment of others' help, the use of technical aids, etc.) and secondary control strategies (an individual's effective influence over his or her emotions, motivational states, and mental representations; social and temporal comparisons; optimism; self-enhancement; control beliefs; coping strategies; religiosity; etc.).

This model is also concerned with the outcomes of frailty, which are also numerous and mainly negative (many have already been described as antecedents). Frailty has the potential to impact all spheres of the life course: health (physical health, cognitive functioning, vitality, death, etc.), well-being (satisfaction in different life spheres, happiness, positive affects, etc.), activities (daily, productive, leisure, cultural, etc.), the frequency and quality of different types of relationships (cohabitants, family, friends, neighbors, professionals, etc.), and exchanges (help, care, visits, etc.) (not all these dimensions have been investigated yet). Frailty has also been considered a predictor of institutionalization of the elderly in nursing homes, hospitals, or other care systems.

Cyclical Model of Frailty

One of the main issues with linear models of frailty is the problematic separation of antecedents and outcomes of frailty. One reason for this is that often short-term antecedents of frailty can also be considered its outcomes. For example, malnutrition, comorbidity, and falls are considered to be both frailty antecedents and outcomes. This is one of the reasons why systemic models have been developed recently. Systemic models emphasize the interactions and processes that relate different systems with respect to frailty.

In the cyclical model (see **Figure 2**), the main assumption is that the process resulting in frailty is generally due to senescence, but is often observed after the occurrence of a trigger event (e.g., a hip fracture, an illness, hospitalization). Generally speaking, most short-term antecedents of frailty are described in the linear model. An important feature of

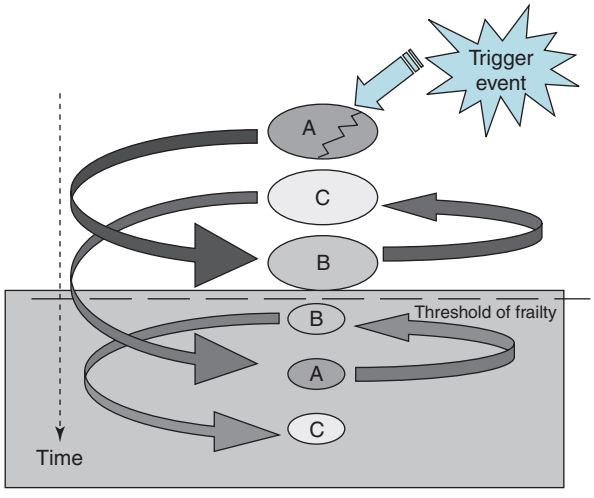

Figure 2 The cyclical model of frailty: a trigger event can initiate a spiral of decline in various resources (A, B, C) that results in frailty when a given threshold in reserves is attained.

this model is that frailty can be set in motion by a change (usually a decline) in different subsystems of the organism. This may occur in different types of systems (physiological, psychological, behavioral, etc.), yet it is in the domain of physiology that this hypothesis (a cycle of frailty) has been presented in greatest detail. This dimension is used in order to describe the cyclical model.

There is evidence for a general decline in the second part of a person's life span, which starts with the decline of a number of physiological characteristics (including creatinine clearance, forced expiratory volume, nerve conduction velocity, insulin sensitivity, muscle mass, strength, and maximum oxygen uptake or VO_2). This process of senescence accelerates around the age of 70 years and progressively erodes the reserves of different systems, which may result in less reactivity and resilience to stressors or even irreversible alterations. Some theories go as far as to generalize that a universally determined threshold of about 30% governs the functions of many body systems. When reserves are above this value, the system has the capacity to react to stress, and although an individual can be qualified as resilient, under this value of reserves the organism shows evidence of failure, which can usually be observed clinically. An important feature of the cyclical model is that in most cases, and across a large part of a person's life span, the individual tends to be resilient. Therefore, damages to the organism are in many cases reversible and can be successfully overcome. This is the case, for example, when some diseases, such as diabetes, cause a general dysfunction that can be treated efficiently, making the symptoms of frailty disappear.

Many of these markers of frailty are related to one another and constitute the key elements of a cycle of frailty, which suggests that deficiencies in several dimensions may accumulate because of their underlying linkages. In particular, this cycle establishes a formal pattern of linkages between mobility and the ability to energize metabolism, whereby inactivity can lead to loss of appetite and subsequent insufficient food intake, resulting in malnutrition. This in turn gives rise to muscular dysfunctions and further decreased activity.

The pathways leading to frailty are varied. Some older people may become frail because of the normative physiological changes in aging that are not based on any particular disease, in which case frailty may be reversible. Others may become frail owing to severe disease and comorbidity downsizing the disposable resources and hence becoming insufficient for reestablishment, in which case it is very likely that the process cannot be reversed and frailty will mark the latter stages of life. A notable exception is the case of a disease that causes symptoms of frailty and that can be partially or completely treated, if the treatment is followed by a restoration of general resources.

The cyclical model designates three main subsystems of frailty: sarcopenia (the process of decline in muscle mass associated with aging), immune dysfunctions (the organism's defense against pathogens and malignancies), and neuroendocrine deregulations (regulatory systems that monitor environmental and other sensory input and maintain homeostatic balance via nerve and endocrine signaling to end organ systems). When one of these subsystems is affected (as represented by the smaller ellipses in **Figure 2**), it has some impact on related subsystems (see B and C in **Figure 2**), which in turn impact the first one (A in **Figure 2**), and so on. These chain reactions, when they seriously challenge the reserves of the subsystem without a reaction of equilibration of the organism, may – after a given threshold is overcome – initiate the cycle of frailty, which is described as a downward declining spiral of the functioning of the organism.

Emerging Issues about Frailty

The emergence of the concept of frailty in gerontological research (with the subsequent clear demarcation between chronic disability and frailty in old age) points to the fact that the oldest-old are not necessarily disabled. But on the other hand, it asserts that a non-chronically disabled older person should not necessarily be considered a robust adult. Frailty may affect a person relatively early on in life, or it may be postponed up to a very advanced age, thanks to good genes, prevention (e.g., nutrition, physical and mental exercise, openness to life experiences), and appropriate strategies of adaptation (SOC, primary and secondary control, a meaningful and coherent identity, etc.). However, frailty appears to be the price that must be paid by most people who live a long life. From the life course perspective, the constantly increasing probability that a human being will live more than 80 years tends to institutionalize frailty as a normal stage of life.

But a set of questions remains to be answered concerning the nature of frailty as a process and concerning the relationship between frailty and chronic disability or chronic dependence.

- *Frailty, a state and a process*. Empirical research, as social policies, needs classifications that allow for the estimation of prevalence and incidence and comparisons across different contexts, populations, or periods of time. Currently, there is no

consensual definition of frailty, but any operationalization remains a working tool. Thus, it is wise to hypothesize that the process of frailty has already started before an older person is even classified as clinically or scientifically frail. And it is important to keep in mind that frailty is a dynamic, evolving, and sometimes reversible process. Rather than considering the performance level of certain functions in absolute terms, changes in suggested markers should be underscored at the individual level. These account for idiosyncratic properties, such as individual baseline measures specific to one's level of functioning in assessing markers of frailty over time. Moreover, focusing on individual assessments and rates of change in these markers respects the dynamic status often attributed to the process of frailty. Such an approach (i.e., one that is concerned with intra- and interindividual variability in trajectories leading from autonomy to various levels of frailty, and then from frailty to death) is desperately needed. It will enable future research to tackle important and unanswered questions. For example, does the transition to frailty generally occur abruptly and rapidly? We may examine the hypothesis of an avalanche-like destruction of the organism or a cascade-like decline in different dimensions of cognitive functioning in such a case. Or does it occur in a smooth and progressive manner? When and how does resilience in different yet related subsystems decrease in efficacy?

- *The link between frailty and chronic ADL dependence and the current organization of the life course's last stages*. Is a chronic disability the outcome of frailty, or does an older person become disabled without going through the process of frailty? Individual-based research reveals that in old age an abrupt transition from independence to chronic dependence seldom occurs and that in almost all cases the pathway to dependence transits through a durable stage of frailty. Conversely, does frailty necessarily lead to disability during old age, and if not, why? In other words, is it possible to die without going through a long-term stage of ADL dependence or an acute degenerative mental and/or physical process? The few existing studies scrutinizing the final years of life provide evidence that a very significant proportion of older people (about half) end their life without going through a stage of chronic dependence. From a life course perspective, some argue that frailty can thus be considered a normal stage in advanced old age, leading either to chronic dependence as the last stage before dying or to a chronic state of frailty close to death. But more research on larger samples and across different cultures is needed to check this provisory (and frail) state of knowledge. Further, the definition of chronic or long-term dependence may vary largely across studies (with durations ranging from more than a year to 3 months before decease), which directly affects the estimations of older people who have died while frail and those who have died after a stage of chronic dependence. Until now, studies concerning the frail elderly were mainly descriptive, and the few predictors of the end-of-life trajectories referred to ascribed characteristics of the individual (e.g., sex, age). An important step would be to establish the degree to which specific genetic factors, health antecedents, styles of adaptation, past behaviors, and lifestyle, but also social and service environments, orient life trajectories during old and very old age. Knowledge about such enabling characteristics – and not only about predisposing factors – would help to, echoing a now-classic statement in gerontology, add life to years and not years to life.
- *Methodological issues*. From a methodological point of view, research on frailty as a process and, more generally, research on the life trajectories in advanced old age would benefit from the following suggestions:

1. Special attention should be given to individual health transitions. Key questions concerning the duration of frailty, its reversibility, its degree of severity, and its necessary preceding role before ADL dependence can only be tackled by empirical data based on repeated measures at the individual level rather than on single assessments at the group level. Longitudinal research designs (preferably long-term) are thus required.
2. It is necessary to follow the elderly to the end of their lives when studying the relationship between frailty, the organization of the last stages of life, and dying. Life trajectories must then be reconsidered retrospectively. Longitudinal studies on the oldest-old should be organized in a way that enables researchers to secure the recollection of data up to the extinction of the sample. Access to the individuals' medical records provides valuable information on their health trajectory and health consumption.
3. Qualitative and quantitative changes between health statuses can not be effectively tested with classical statistical models. Advanced mathematical models, including linear and non-linear dynamical systems, allow researchers to model frailty as the quantitative accumulation of losses that occur with greater probability in older than in

younger ages and that may lead to a qualitatively different stage of life.

Implications for Policy and Practice

From an anthropological as well as a philosophical point of view, vulnerability is an ontological element of the human condition, and autonomy is an always-vulnerable achievement in life. Frailty, as defined previously, appears as the specific form that vulnerability takes when advancing through old and very old age. Coping daily with this increased vulnerability and preserving as much autonomy as possible is the great challenge during the last stages of life. It is a challenge that contemporary elderly and societies should tackle with continuity, but also with the consciousness concerning how normal frailty is in old age, especially in very old age.

With these preliminary considerations now stated, the interventions that partially prevent, postpone, or limit the impact of losses due to frailty may be envisaged with some confidence at different stages of the frailty process. There is strong evidence to support the claim that primary prevention can be achieved through an adequate lifestyle (though frailty appears sometimes in spite of healthy lifestyles) and in particular by a certain level of physical activity, mental exercise, a balanced nutritional program, the maintenance of social and emotional ties, and a general openness toward life. Lifestyle interventions may be the most effective way of preventing frailty, as they address multiple functional systems in contrast to specific disease-focused interventions (e.g., antihypertensive treatments). The process of frailty is certainly inevitable for the oldest-old. However, certain components of the lifestyle of the elderly may prevent or at least postpone frailty.

As frailty is also related to the individual's environment, many domains of life are concerned with the prevention of frailty. Trigger events such as falls can be prevented by adapting public buildings and means of transport to the needs of an aging population. Secondary prevention programs that include physical activity, memory training, and nutrition have shown good results in slowing the development of and even reversing some symptoms of frailty. Tertiary strategies of intervention are perhaps the most difficult to implement, as there is a lack of knowledge about the link between frailty and chronic disability. This is particularly true regarding the pathways from the former to the latter. More evidence on this issue would be a great contribution for policy aiming to avoid or at least limit the most negative outcome of frailty.

More generally, as frailty is a many-sided and multidimensional phenomenon that tends to mark a normal stage in the advanced lives of contemporary human beings, it appears that no general and uniform program should be developed to fight frailty in old and very old age. Social and health policies should recognize instead that frailty is an important characteristic of old age, and policymakers should find ways of implementing a flexible network of programs and services that will answer on an individual basis to the variety of needs, difficulties, incapacities, and demands of frail elders.

See also: Behavioral Genetics; Cellular Aging: Growth Factors and Cellular Senescence; Depression; Diet and Nutrition; Falls; Disability, Functional Status and Activities of Daily Living; Health Care and Services; Homeostasis, Homeodynamics and Aging; Life Course; Markers of Aging; Mobility and Flexibility; Osteoporosis and Aging Related Bone Disorders; Physical Therapy and Rehabilitation; Politics of Aging; Psychological Well-Being; Self-Regulation, Health, and Behavior; Social Networks, Support, and Integration; Stress: Physiological; Theories of Aging: Biological; Theories of Aging: Psychology; Theories of Aging: Social.

Acknowledgments

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Gastrointestinal System: Function and Dysfunction

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Glossary

Achalasia – Motility Disorder characterized by the absence of normal esophageal peristalsis and incomplete or absent relation of the sphincteric barrier between the esophagus and stomach.

Crohn's Disease – Chronic inflammatory bowel disease affecting any portion of the gastrointestinal tract, marked by strictures and fistulae.

Gastroesophageal Reflux Disease (GERD) – Esophageal dysfunction with symptoms of heartburn, regurgitation, difficulty swallowing, and chest pain.

Gastrointestinal System – Interrelated organs whose function is to achieve proper nutrition by the digestion and absorption of ingested nutrients, and whose normal function includes production of enzymes and hormones as well as proper motility and excretion of wastes.

Ischemia – When blood flow is insufficient to nourish the tissues resulting in their dysfunction or death.

Peptic Ulcer – A defect in the lining of the stomach, duodenum, or esophagus due to a combination of an excess of aggressive factors that cause ulcers or a decrease of resistance factors that protect against them.

Introduction

The gastrointestinal system consists of many interrelated organs. It serves a variety of functions, all of which are crucial to the proper working of the body. The primary function of the gastrointestinal system is to achieve proper nutrition by the digestion and absorption of ingested nutrients; normal function includes the production of enzymes and hormones as well as the maintenance of proper motility, including excretion of wastes. Dysfunction of the system is common and may be the result of an abnormality of one of the component organs or of a process that is disordered more generally and affects several organs simultaneously. Dysfunction of the gastrointestinal system is a frequent problem in the elderly and a major reason for visits to the health-care worker.

Function

Anatomy

The gastrointestinal tract is composed of both hollow and solid organs. The hollow organs are arranged as a continuous tube beginning with the mouth and extending to the anus. The solid organs are connected to the hollow organs by way of ducts. A schematic representation of gastrointestinal anatomy is depicted in **Figure 1**.

The proximal extent of the gastrointestinal tract is the oral cavity. As a bolus of food is taken into the mouth, the digestive process begins with chewing (or mechanical disruption of the food) and is closely followed by secretion of saliva. Saliva contains enzymes such as amylase that help break down starches into sugars. Openings into the oral cavity exist for secretions from the major salivary glands, including the parotid, sublingual, and submaxillary glands, as well as the minor salivary glands inside the lips. The food bolus is then swallowed as it is propelled backward by the tongue into the oropharynx, and then into the esophagus.

The esophagus is a tubular structure approximately 25 cm in length that serves as an anatomic conduit between the mouth and the stomach. The point at which the esophagus joins the stomach is termed the gastroesophageal junction. This is an area characterized by a sphincter muscle that functions as a one-way valve, allowing food into the stomach but not allowing gastric contents to reflux back up again. The esophagus is lined by layers of flat cells heaped upon one another, collectively known as a stratified squamous epithelium. Mucus-producing glands help

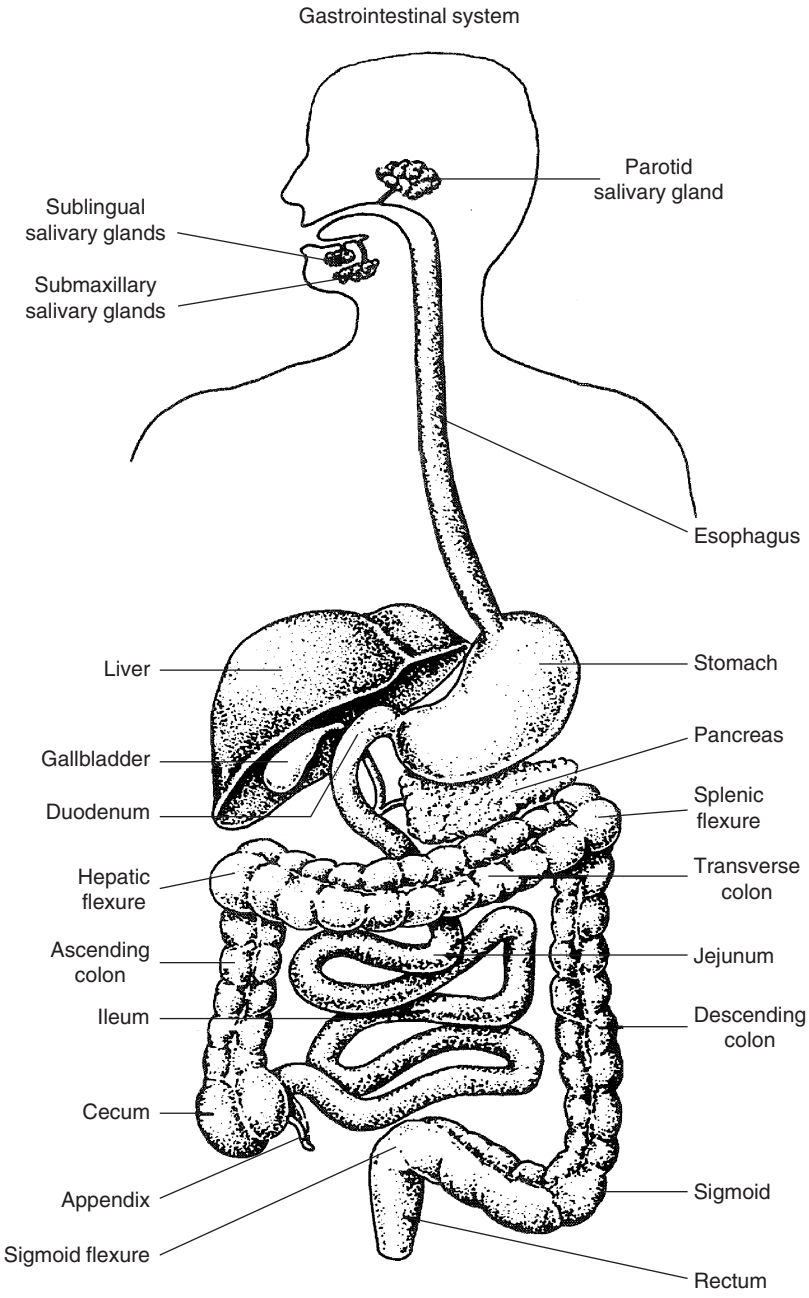

Figure 1 A schematic representation of gastrointestinal anatomy. Printed with permission from Solvay Pharmaceuticals, Inc.

the saliva lubricate the passage of food. Food is propelled through the esophagus and past the gastroesophageal junction by peristalsis to enter the stomach.

The stomach is located in the upper and midabdomen and is divided into four distinct regions: fundus, body, antrum, and pylorus. Although the lining of the stomach is composed of a single layer of tall (columnar) cells, each region of the stomach has a distinct microscopic architecture with specialized cells. For example, the fundus and body contain parietal cells, which make acid, and chief cells, which make pepsin, a digestive enzyme that breaks down proteins. G cells, which produce gastrin, a hormone that stimulates the stomach to produce acid, are located exclusively in the antrum. The pyloric sphincter is the anatomic as well as the functional landmark that separates the stomach from the small intestine.

The small intestine is the longest organ in the body. It measures approximately 22 feet and is divided into the duodenum, the jejunum, and the ileum. The longest segment is the jejunum. Like the stomach, the

lining of the small intestine is a single layer of epithelial cells of the columnar type; however, it has three specialized anatomic modifications to increase the surface area for absorption: the valvulae conniventes, which are bucklings of the lining of the small intestine; the villi, which are finger-like projections of the mucosa; and the microvilli, which are hair-like modifications of the superficial cell membrane at the brush border, or the barrier between the lumen and the cell. The ileocecal valve separates the small and large intestines and thereby slows the transit of nutrients through the small intestine, thus facilitating digestion. It also protects the small intestine from the bacteria of the large intestine.

The large intestine, or colon, is 4–5 feet long and extends from the ileocecal valve, usually located in the right lower quadrant of the abdomen, to the anus. The appendix is attached to the cecum. Although not important in the digestive process, the appendix may play an important role in the immune system early in life; it atrophies with advancing age. The large intestine is divided anatomically into several regions, including the ascending colon, transverse colon, descending colon, sigmoid colon, and rectum. The colon, like the small intestine, is lined with a columnar epithelium, but the microvilli on the colonic cells are much less prominent than those on the small intestinal cells. The most distal part of the gastrointestinal tract is the anus, and stool leaves the body after passing the anal sphincter. The lining of the anus consists of a stratified squamous epithelium, similar to that found in the esophagus and the skin; all these organs share some diseases because of their common cell type.

The other important structures that are part of the gastrointestinal system are the liver, pancreas, and gallbladder. The liver is located in the upper abdomen on the right and weighs approximately 4 pounds in men and 3 pounds in women. The liver produces bile, which helps digest fats, and the bile drains into the small intestine by way of the bile ducts. In addition to aiding in the digestion of foods, especially fats, the liver is the most important organ in the detoxification of drugs and medications. The gallbladder is located near the liver and is connected to the bile ducts via the cystic duct. It stores bile until it is needed for digestion. Finally, the pancreas is found in the mid-abdomen. It weighs about one-quarter pound, and its secretions drain into the small intestine by way of the pancreatic duct. It functions to help digest all major food classes by secreting a variety of enzymes: amylase to digest starch, lipase for fats, and trypsin and chymotrypsin for proteins. Of course, the pancreas also makes insulin that prevents diabetes.

Secretion and Digestion

The regulation of fluid balance is crucial to survival. Approximately 9 L of fluid enters the gastrointestinal tract per day. Of that amount, about 2 L is ingested by mouth. The remaining 7 L consists of fluids secreted by the various gastrointestinal organs. Ninety-eight percent of the total amount of fluid that enters the gastrointestinal tract is reabsorbed in the small intestine and the colon.

Of the secreted fluids, 1 L per day is generated in the mouth as saliva. Saliva contains salivary amylase, an enzyme that is useful in the preliminary breakdown of carbohydrates. Gastric secretion produces about 2 L of fluid per day, consisting primarily of acid and mucus. It has been the classic teaching that as one ages, the capacity to secrete gastric acid also diminishes. However, this adage has been questioned, and it is now believed that, if a person enjoys good health, the stomach will make a normal amount of acid. Sometimes it is difficult to know what normal is in an elderly person because the range of normal values that have been established is based on young, not old, adults. The liver produces an additional liter of fluid, bile. Bile is a complex fluid made up of electrolytes, bile acids, bilirubin, cholesterol, and lecithin; it helps digest fats. Output from the pancreas as pancreatic juice accounts for an additional 2 L of fluid per day and is central to the digestion of already partially degraded nutrients. Finally, an additional 1 L per day is derived from succus entericus or the fluids secreted by the gut itself. Only about 1–2 L of the original 9 L of fluid that enters the jejunum is left to pass into the colon, and of that amount, only 200 ml is excreted into the feces. Wet feces are passed as diarrhea, whereas overly dry feces result in constipation.

Many hormones play important roles in normal gastrointestinal function. These molecules serve to regulate various events in gastrointestinal physiology. Some hormones oppose the actions of other hormones, thereby leading to exquisite control via a continuous balance of regulatory and counterregulatory forces. For example, gastrin is a peptide secreted by the stomach and is the major hormonal stimulant to the production of acid by the gastric parietal cells. Gastrin also helps regulate the various muscle sphincters throughout the gastrointestinal tract and the motility of the digestive organs, their blood flow, and fluid balance. Somatostatin is an antagonist to gastrin release and therefore inhibits the production of acid by the stomach as well as some of the other functions of gastrin. Another hormone, cholecystokinin (CCK), is produced by cells in the duodenum and jejunum and regulates the release of bile from the

gallbladder. Secretin is produced in the duodenum and stimulates the flow of pancreatic juice. In general, hormones have multiple functions and complex interactions.

Digestion may be defined as the intraluminal breakdown of food. It proceeds in an orderly way from the mouth through the digestive tract. The purpose of digestion is to reduce complex nutrients into their simplest forms to allow for absorption by the small intestine. For example, starches and sugars are sequentially broken down from polysaccharides (many sugars) to oligosaccharides (few sugars), and then ultimately to monosaccharides (one sugar) before they are absorbed and then utilized.

Mastication (chewing) serves to break up large food particles, thereby increasing the total surface area of the food that will be exposed to digestive enzymes. In the mouth, salivary amylase initiates the preliminary digestion of carbohydrates. Once food passes into the stomach, further mechanical and chemical digestion occurs. Churning and grinding of particles in the gastric lumen mechanically reduces their size and is accompanied by chemical digestion in an acid environment.

The most important site of digestion of all dietary intake is the small intestine. The thick, semi-fluid mass of partly digested food (chyme) is delivered from the stomach to the duodenum at a controlled rate to allow for proper mixing with digestive enzymes. The hormones secretin and CCK stimulate the secretion of pancreatic enzymes and bile. These, in turn, facilitate further breakdown of food particles. In the small intestine, pancreatic enzymes such as amylase, lipase, and proteases, all acting under proper luminal pH, help to digest carbohydrates, fats, and proteins, respectively. Pancreatic amylase is the primary enzyme involved in carbohydrate digestion. It digests polysaccharides into short oligosaccharides. Protein digestion, which begins with acid and pepsin in the stomach, continues with the pancreatic proteases trypsin and chymotrypsin. Lipase acts within the pH ranges of the intestine to break down fats from triglycerides to glycerol and free fatty acids. In the liver, bile salts are excreted in bile, which then passes into the small intestine. Bile salts help to solubilize fat and fat-soluble vitamins by forming compounds known as micelles. Micelles are critical to the efficient transport of fats across the small intestinal absorptive surface. Finally, brush border enzymes, including disaccharidases (such as lactase, sucrase, and maltase), peptidases, and lipases, help to complete the digestion of nutrients into their simplest forms to permit their passage across the small intestinal wall.

Last, the process of digestion is enhanced by reabsorption of certain materials central to digestion, which, thereby, allows for their reuse. For example, the total amount of bile acids in the body is kept at a steady level, because more than 98% of bile salts produced by the liver are reabsorbed in the terminal ileum and recirculate to the liver by a pathway known as the enterohepatic circulation. The small amount of bile salts lost into the colon each day is replaced by an equal amount synthesized by the liver, thus keeping the total body pool of bile salts constant.

Nutrition and Absorption

After appropriate digestion of nutrients, the function of the gastrointestinal tract is to absorb these nutrients so they may be used for a variety of cellular processes.

Absorption occurs across the cells lining the small intestine and proceeds via one of several mechanisms. The first is passive absorption, in which material moves along an electrochemical gradient. The second is facilitated transport, in which absorption of one substance is coupled to the transfer of another substance. Finally, there is active transport, in which transport occurs against an electrochemical gradient and requires an expenditure of metabolic energy.

The primary nutrients are fats, carbohydrates, and proteins. All are absorbed in the small intestine. Complex fats are degraded to free fatty acids. Free fatty acids are relatively insoluble in water and require the help of bile salts to solubilize them, a process resulting in the formation of micelles. Micelles can transport fat through the relatively hydrophilic (water-permeable) small intestine into the absorptive cell, where the micelle is disrupted and the now free fatty acid is able to diffuse passively across the cell surface. Once within the cell, the fatty acids are resynthesized into triglycerides by the process of esterification. Then they are packaged for export from the cell in the form of chylomicrons and very low density lipoproteins and ultimately are carried to the liver by the lymphatics.

Carbohydrate absorption occurs in the small intestine, where monosaccharides are absorbed via facilitated and active transport. Proteins have specific carrier mechanisms allowing for their transport in the form of peptides and single amino acids.

Several other molecules absorbed in the small intestine are critical to the maintenance of normal body function. Calcium is absorbed primarily in the duodenum. Its absorption is regulated by vitamin D through the synthesis of a calcium-binding protein. Iron is absorbed in the duodenum by a carrier-mediated mechanism. Vitamin B_{12}, or cyanocobalamin, is absorbed after being bound to intrinsic factor, another substance that is produced in the stomach.

The vitamin B_{12}–intrinsic factor complex actually forms in the upper small intestine with the help of pancreatic juice and protects the vitamin B_{12} until it reaches the ileum, where it is absorbed. Folate is ingested in the form of polyglutamates in many foods. Brush border enzymes hydrolyze polyglutamates to monoglutamates that are transported by passive diffusion and a carrier-mediated process in the duodenum and upper jejunum, respectively. Last, fat-soluble vitamins such as vitamins A, D, E, and K are transported in micelles in a fashion similar to that of fat molecules.

Motility

The motility of the gastrointestinal tract is complex, and normal motility is critical to proper digestion. In order for gastrointestinal motility to be effective, it must be coordinated with other intestinal functions such as secretion and absorption, and it must be regulated and integrated in a precise fashion.

Swallowing is an exceedingly complicated process that involves coordinated movements of the tongue, the muscles of the mouth, and the posterior oropharynx, all modulated by multiple cranial nerves. A bolus of food moves down the esophagus in an orderly fashion in a motor pattern known as peristalsis. When a swallow is initiated, a peristaltic wave of contraction proceeds from the proximal esophagus to the distal esophagus, helping to propel the bolus of food downward. In a coordinated fashion, the lower esophageal sphincter relaxes when the peristaltic wave reaches it, thus allowing food to pass into the stomach.

Beyond the gastroesophageal junction, normal gastrointestinal motility occurs in two patterns: fasting and fed. In the fasting pattern, there are periods of relative rest that alternate with periods of contractile activity. The time of relative rest is known as phase I, and the active period is termed the migrating motor complex (MMC). The MMC consists of phase II, characterized by irregular contractions, and phase III, characterized by a short period of intense contractions. The MMC proceeds in an orderly fashion from the stomach to the distal small intestine. It is often called the intestinal housekeeper because of its action to sweep intestinal food contents onward.

The fed pattern is typified by frequent contractions that are somewhat irregular. This pattern starts immediately after a meal is ingested and replaces the fasting pattern at that point. The fed pattern is dependent on the type of meal ingested. For example, liquid meals produce considerably less prominent contractile activity than solid meals. The duration of this motility pattern depends on both the quantity and the type of food ingested. Once the stomach has emptied and the intestinal contents have been absorbed, the fasting motility pattern returns. The time it takes for half of a liquid meal to exit the stomach is about 20 min, whereas the comparable time for a solid meal is about 90 min.

The purposes of gastrointestinal motility following a meal are to allow for storage, to mix the food, to expose digested nutrients to the absorptive surface, and to evacuate the wastes. Toward these ends, different regions of the stomach and upper intestine act differently. The proximal stomach (the fundus) functions primarily as a reservoir for liquids and contracts in a predictable and orderly way to squirt liquids into the distal stomach, through the pylorus, and into the duodenum. A major function of the antrum is to grind and mix solid food. This task is achieved by coordinated contractions and relaxations of the antrum and the pylorus; liquids and very small solid particles (< 1 mm) pass the pylorus, while larger particles are rejected and subjected to repetitive churning. Once in the small intestine, the partly digested material, or chyme, progresses slowly but steadily as a result of intermittent contractions typical of the fed pattern.

The integration of the motor function of the gut is complicated. It is determined by controls at the level of the enteric, autonomic, and central nervous systems. The enteric nervous system is found within the wall of the gut in two plexuses, the myenteric and submucosal. The enteric system is coordinated by a means of cell-to-cell communication known as the paracrine system, as well as by the hormonal system, which has its stimulatory and inhibitory messages carried to its target cells via the bloodstream. The autonomic nervous system includes the sympathetic and parasympathetic nervous systems and mediates responses along reflex pathways. These systems are connected to the central nervous system. The brain, then, plays an important part in the coordination of integrated functions of the gastrointestinal tract. The precise roles of hormones and neuropeptides on the gut-related nervous system, although clearly important, are not yet well defined for many of the substances. Gastrointestinal motility is a complex and well-integrated activity that requires multiple layers of appropriate regulation for the entire system to function properly.

Dysfunction

Dysfunction of the gastrointestinal tract is a broad topic, encompassing a wide range of anatomic and physiological abnormalities. Dysfunction may be seen at any age, but there are important special

considerations that must be made when evaluating an elderly patient. Indeed, the same disease seen at different phases of life may appear quite dissimilar, and the possibilities for gastrointestinal dysfunction are significantly more extensive in the elderly than in a younger person.

The Oral Cavity

The mouth is an often-forgotten portion of the gastrointestinal tract in medical texts. However, knowledge of oral cavity dysfunction is important not only for the dentist but also for the gastroenterologist, and may be a clue to the cause of disease elsewhere in the body. Nutritional deficiencies, particularly the B vitamins (e.g., niacin, riboflavin), may present as glossitis (inflammation of the tongue) or angular stomatitis (inflammation at the corners of the mouth), respectively. Certain skin disorders such as pemphigus and pemphigoid often have coincident oral manifestations. Fungal infection of the mouth (thrush) is not uncommon, especially in elderly patients treated with oral antibiotics; viral diseases such as herpes simplex infections often are seen in patients who have an underlying malignancy. Finally, epidermal or squamous cell carcinoma of the lip and tongue is seen, especially in elderly men who have a history of heavy tobacco or pipe smoking.

The Esophagus

Gastroesophageal reflux disease (GERD) is the most common esophageal dysfunction. Its chief symptoms are heartburn, regurgitation, dysphagia (difficulty swallowing), and chest pain. Approximately 40% of the population of the United States reports an episode of heartburn at least monthly, and antacids are used frequently. GERD is usually well tolerated but may lead to serious complications, including esophagitis, strictures, ulcers, and cancer. The etiology of GERD is thought to involve four components: lower esophageal sphincter incompetence, abnormal esophageal clearance of acid and refluxed material, delayed gastric emptying, and the irritant effect of refluxed gastric contents. Symptoms of GERD may be quite troubling and may be confused with angina (i.e., chest pain of a cardiac origin). A hiatal hernia, or a defect in the anatomic structures that normally confine the stomach within the abdominal cavity, is frequently present in patients with symptomatic GERD.

Motility disorders of the esophagus often are found in patients who complain about chest pain or dysphagia. Achalasia is one such motility disorder and is characterized by the absence of normal esophageal peristalsis, as well as by incomplete or absent relaxation of the sphincteric barrier between the esophagus and stomach. Patients have difficulty swallowing that is progressive over years. An important consideration in the elderly patient is pseudoachalasia, which is an achalasia-like clinical picture that may be caused by a malignancy infiltrating the nerves at the level of the gastroesophageal junction. Other motility disorders also may produce significant symptoms: diffuse esophageal spasm, a condition in which muscular contractions are simultaneous (i.e., non-peristaltic), and the nutcracker esophagus, in which high-amplitude simultaneous contractions cause chest pain. Systemic diseases such as thyroid disease, diabetes, and scleroderma also may produce esophageal dysmotility. Some medications, most commonly certain potassium supplements, quinidine, non-steroidal anti-inflammatory medications, alendronate, and tetracycline, usually when taken without sufficient liquid to wash them out of the esophagus, can stick in and injure the esophagus, thereby producing an ulcer or stricture.

Swallowing difficulties may be caused by dysfunction at the level of the oropharynx, as well as by disorders of the esophagus or the gastroesophageal junction discussed previously. Oropharyngeal dysphagia is an important cause of such difficulties in the elderly. It may be caused by nervous system diseases (e.g., cerebrovascular accidents, Parkinson's disease, multiple sclerosis, and brain stem tumors), skeletal muscle diseases (e.g., polymyositis, or inflammation of the muscles), local anatomic factors (e.g., bone spurs and arthritis of the cervical vertebrae), and external pressure on the esophagus from the aorta either by an aneurysm or by the enlargement and uncoiling of the aorta that occurs with advancing age.

Esophageal tumors are among the most common malignancies in the world, yet they are relatively infrequent in the United States. They are often related to significant alcohol use and cigarette smoking and are more common in males than in females. One type of esophageal cancer, called adenocarcinoma, usually arises from abnormal tissue termed Barrett's epithelium near the gastroesophageal junction. Barrett's epithelium is a consequence of GERD, and occurs when the esophagus heals eroded, ulcerated areas with a tissue resembling the normal lining tissue of the stomach. In the esophagus, such gastric tissue has the potential to become malignant over many years. Periodic surveillance with an endoscope detects this premalignant tissue early and therefore permits therapy for such cancers earlier than would otherwise be possible. Unfortunately, however, most esophageal cancers are incurable at the time of diagnosis.

The Stomach

Peptic ulcer diseases (i.e., gastric and duodenal ulcers) are frequent medical problems. There are approximately 500 000 new cases and 4 000 000 recurrences in the United States each year. Approximately two billion dollars a year are spent on medications for ulcers, and it has been estimated that care for peptic ulcer disease represents about 10% of the total medical costs for all digestive diseases. About one-third of patients with peptic ulcer disease are older than 60 years at the time of diagnosis; its mortality in patients over age 75 is twice that of patients age 65–74, and more than 10 times that of patients age 45–54, although this must be viewed in light of the frequent coexistence of multiple diseases in the elderly individual.

A peptic ulcer may be defined as a defect in the lining of the stomach, duodenum, or, less commonly, the esophagus (as a result of acid reflux). It is due to a combination of either an excess of aggressive factors that tend to cause ulcers or a decrease of resistance factors that tend to protect against them. Duodenal ulcers are more common than gastric ulcers. Peptic ulcer disease is a significant problem in the elderly, in whom presentations may be atypical, the onset of disease may be severe with hemorrhage or perforation, and the prognosis is not necessarily as favorable as in the young because of misdiagnosis and a hesitation to be aggressive in therapy.

The aggressive factors in excess are acid and pepsin, but it is now believed that most gastric and duodenal ulcers in the elderly (as well as in the young) result from infection with a bacterium known as *Helicobacter pylori* or from non-steroidal anti-inflammatory drugs (NSAIDs); therefore, most ulcers are curable with antibiotics or by stopping the NSAIDs. Decreased resistance of the stomach epithelium is commonly induced by NSAIDs and cigarette smoking.

Disorders associated with reduced gastric secretion also exist. It generally has been believed that gastric secretion diminishes with advancing age, but this has been questioned, and it is now believed that the healthy elderly person has a healthy stomach that makes a normal amount of acid. In atrophic gastritis, inflammation of the lining of the stomach is present, probably caused by an autoimmune (self-destructive) mechanism. This leads to destruction of the acid-producing cells of the stomach. When these cells undergo atrophy, in addition to decreasing their acid production, they become incapable of producing intrinsic factor. The presence of intrinsic factor is crucial to normal vitamin B_{12} absorption; without it, vitamin B_{12} absorption is disrupted and pernicious anemia develops. Both atrophic gastritis and pernicious anemia are particularly common in the elderly. Moreover, the presence of atrophic gastritis has been linked to the development of gastric malignancies.

Gastric motility may be disordered in the elderly, resulting in a variety of symptoms. When gastric emptying is delayed, bloating, belching, and vomiting can develop as the stomach distends with retained food matter. If the partially digested material remains for a long enough period of time, a concretion known as a bezoar may form; bezoar formation is especially common in edentulous subjects who have had some gastric surgery and who eat foods that are difficult to digest, such as celery and oranges. Gastric motility is known to be delayed as a result of certain systemic diseases, most notably diabetes, and as a consequence of some gastric surgery. Medications often affect the movements of the stomach, and in the elderly, who frequently are taking multiple medications, motility disturbances are potentially important side effects.

Rates of gastric cancer, particularly involving the distal stomach, have been decreasing over the past several decades, but gastric cancer still remains an important cause of cancer death in the world. Success in curing gastric cancer is highly dependent upon the stage at which the cancer is detected. An important association is known between having had prior gastric surgery and the subsequent development, often 20 or more years later, of gastric cancer. This is a significant risk for the elderly patient who may have had surgery in the past for control of peptic ulcer disease. A sequential connection between chronic *H. pylori* infection, gastritis, gastric atrophy, and gastric cancer has been theorized, and it is hoped that cure of *H. pylori* will be followed by a decrease in gastric cancer.

The Small Intestine

Small intestinal dysfunction is characterized by maldigestion and malabsorption. Maldigestion may be caused by alterations in the production or function of the usual digestive enzymes, whereas malabsorption generally results from the loss of the normal absorptive surface of the intestine or disruption in the normal absorptive process. Intestinal function is well preserved with aging, and only the ability to absorb calcium and vitamin D may decrease to a clinically significant level. The ability of the small intestine to absorb monosaccharides has been shown to decrease with aging, and the pattern of fat absorption also appears to be different in the elderly, although such relative deficiencies do not lead to significant abnormalities; rather, they are merely curiosities of the aging process.

A variety of conditions lead to maldigestion, including pancreatic insufficiency, in which there is a lack of adequate pancreatic enzyme secretion needed for the normal digestion of fats, starches, and protein. Inadequate amounts of bile salts in the small intestine, which may occur in certain liver or bowel conditions, can lead to problems with fat digestion. Specific carbohydrate enzyme deficiencies may lead to carbohydrate maldigestion. Patients who have had prior gastric surgery may, as a result, have a gastric remnant that produces relatively little acid or that is ineffective in mixing digestive juices and food. Both of these situations may lead to decreased digestion.

Certain conditions lead to a loss of the normal absorptive surface of the small intestine. When the normal villous architecture of the jejunum is disrupted, the surface area becomes inadequate for proper nutrient absorption, and malabsorption occurs. This is clinically apparent when it causes chronic diarrhea, often accompanied by evidence of a deficiency of certain vitamins and minerals usually absorbed in the small intestine. Diseases that affect the small intestine and cause malabsorption include celiac sprue and lymphoma. An important concern in a patient with long-standing celiac sprue is an increased risk of malignancy. Both lymphoma and carcinoma can develop as a complication of sprue and affect the esophagus, stomach (carcinoma), or the bowel (lymphoma).

Diseases of the intestinal circulation are rare, but nonetheless represent an important cause of gastrointestinal tract dysfunction, especially in the elderly population. Ischemia occurs when blood flow is insufficient to nourish the tissues, and their dysfunction or death results. Although colonic ischemia is the most common form of intestinal ischemia, ischemia of the small intestine (i.e., acute mesenteric ischemia), is responsible for most of the ischemia-related mortality. In acute mesenteric ischemia, the amount of intestine deprived of blood supply is usually large, the diagnosis is usually made late, and the prognosis is poor, with a mortality rate of approximately 60–80%. This condition has been diagnosed increasingly as the overall population in the country has become older and as clinicians have become more familiar with the spectrum of ischemic diseases of the intestine. When a short length of the small intestine is deprived of blood because of such varied conditions as a strangulated hernia, vasculitis, or trauma, it is termed focal segmental ischemia of the small bowel. This condition usually requires surgical intervention but has a good prognosis. Last, chronic mesenteric ischemia, or intestinal angina, is a condition caused by atherosclerosis (or narrowing) of the mesenteric vessels. Patients with this problem develop abdominal pain or discomfort after eating, and the pain then slowly abates over several hours. They may develop malabsorption if the ischemic disease is long-standing and damages the absorptive lining of the intestine. This condition can be treated surgically, after which prognosis is good.

The Large Intestine

Despite anecdotes to the contrary, most healthy elderly persons move their bowels with normal frequency (i.e., five to seven times weekly). Nonetheless, diarrhea and constipation are common complaints with aging, just as they are in the younger years.

Diarrhea may be defined either as an increase in the volume or in the frequency or a decrease in the consistency of stools. Of the 9 L of fluid that passes through the small intestine each day, approximately 1–2 L enters the colon, and only 200 ml passes out of the body in the stool. In the elderly, complaints about increased frequency of bowel movements are actually often related to fecal incontinence due to constipation with run off of liquid stool around a rectal stool mass rather than to diarrhea.

Diarrhea usually is due to changes in the normal fluid regulation by the small and large intestines. Sometimes, diarrhea occurs when there is an accumulation of poorly absorbable substances in the colon. Examples of this in the elderly include intolerance to milk and dairy products caused by various enzyme deficiencies (such as lactase deficiency leading to lactose intolerance) and intake of poorly absorbable substances, such as sorbitol in diet candies or magnesium in antacids or laxatives (e.g., milk of magnesia). Diarrhea may also occur due to the active secretion of fluid that overwhelms the ability of the colon to reabsorb it; this may be caused by a hormone known as vasoactive intestinal peptide and certain bacterial toxins, such as cholera toxin. Inflammation of the lining of the intestine may lead to increased frequency of loose stools, which can occur in inflammatory bowel disease (ulcerative colitis or Crohn's disease) or in severe constipation, in which hard masses of dehydrated feces may irritate the intestinal lining and lead to an outpouring of mucus. Laxative use promotes loose stools, and studies have shown that surreptitious laxative abuse increases with aging. Antibiotics often cause gastrointestinal upset and diarrhea as side effects and are an important cause of colitis in the elderly. Alterations in intestinal motility may lead to diarrhea and, in the elderly, can occur in the setting of long-standing diabetes as well as in hypo- or hyperthyroidism (an underactive or overactive thyroid gland, respectively).

It generally has been believed that people become more constipated as they get older, but there is no scientific evidence to support this. In otherwise healthy old people, no abnormalities of the motor function of the large intestine have been shown. There are, however, alterations in the sensitivity and capacity of the rectum. Constipation is a term used to describe a relative lack or difficulty of bowel movements as compared to an individual's prior bowel pattern, and gastrointestinal tract dysfunction must be considered only when a change has occurred. In the elderly, constipation often is the result of decreased sensation to distension in the rectum, where stool is stored, so that large volumes of stool accumulate before the patient has the urge to defecate; this may even lead to fecal impaction. Immobilization, prolonged bed rest, long-standing laxative use leading to damage to the nerves of the colon, hypothyroidism, and depression all have been associated with constipation in older people, as have disorders of defecation due to abnormalities of the muscles of the pelvic floor. The latter is most common in elderly women whose pelvic muscles have been damaged by multiple childbirths earlier in life. Complaints of constipation, however, may also be indicative of a structural problem such as cancer, and because the incidence of cancer of the colon increases with age, a change in bowel habits is a key symptom that may help in the early detection of a colon tumor (**Tables 1** and **2**).

Table 1 Common gastrointestinal complaints in the elderly and their usual causes

Complaint	*Cause*
Chest pain[a]	Pill-associated esophagitis
	Tetracycline, quinidine, potassium, NSAIDs, alendronate
	Infections
	Fungus (*Candida*)
	Esophageal dysmotility
	Esophagitis, esophageal ulcers
	Gastroesophageal reflux disease
	Constipation
	Immobilization, prolonged bed rest
	Low-fiber diet
	Insufficient water intake
	Medications
	Pain medications, laxatives, antidepressants
	Hypothyroidism
	Colorectal malignancy
Diarrhea	Ingestion of poorly absorbed substances
	Magnesium-containing antacids
	Laxatives
	Sugar-free candies
	Infections, food poisonings
	Antibiotic-associated colitis
	Pseudodiarrhea
	Watery stool around an obstruction
	Fecal incontinence
	Hyperthyroidism
	Diabetes

[a] Must exclude cardiac sources first.

Diverticula are outpouchings of the wall of the intestine, usually found in the descending and sigmoid colon, just above the rectum. They are believed to arise in areas of weakness of the intestinal wall where high intraluminal pressures occur because of vigorous muscle contractions. The incidence of diverticular disease increases with advancing age to greater than 50% in the ninth decade of life. Population studies show that diverticula formation can be diminished by eating a high-fiber diet; there is no scientific proof that patients with diverticulosis should avoid fruits, nuts, seeds, and skins. Diverticulosis is progressive and the number of diverticula increase over time. Diverticulosis may be complicated by bleeding and by inflammation called diverticulitis.

Inflammatory bowel disease (i.e., ulcerative colitis and Crohn's disease) afflicts nearly two million people in the United States. Historically, inflammatory bowel disease has been said to have a bimodal age distribution, with a peak incidence in the third and fourth decades and then another smaller peak in the sixth

Table 2 Myths about gastrointestinal disease in the elderly

Myth	*Fact*
Pills can be swallowed without water	Adequate liquid is necessary to wash down pills to avoid pill-induced esophageal injury
With aging, the stomach no longer produces acid	The healthy elderly person has a healthy stomach that makes a normal amount of acid
Digestion becomes more difficult with aging	Intestinal function is well preserved with aging; only absorption of vitamin D and calcium decrease
Bowels relax with age; old people become constipated	No evidence of increased constipation or abnormal intestinal motor function in the healthy elderly

and seventh decades. It is now believed that much of the colitis that appears as a new entity in the population older than 50 is probably infectious or ischemic colitis and is not true inflammatory bowel disease.

Ulcerative colitis is a chronic inflammatory disease of the colon that almost always begins in the mucosa of the anorectal junction and extends proximally for a varying length. The disease is limited to the mucosa, or innermost layer, of the colon. Patients usually have bloody diarrhea as their chief complaint. There is an increased risk of cancer in patients with long-standing (i.e., lasting more than 10 years) ulcerative colitis, and that risk is progressive with increasing duration of disease. By contrast, Crohn's disease, the other chronic inflammatory bowel disease, is a chronic transmural disease that can affect any portion of the gastrointestinal tract from the mouth to the anus. The hallmarks of the disease are strictures and fistulae. Patients frequently present with abdominal pain, diarrhea, fever, or symptoms of bowel obstruction; however, in the elderly, presentations are more subtle and atypical than when disease onset is at a younger age, leading to delays in diagnosis or incorrect diagnoses. Patients who have the onset of either ulcerative colitis or Crohn's disease after the age of 50 may have a worse short-term prognosis than when the disease presents in younger patients; the need for surgical intervention may be more common in older patients with late-onset inflammatory bowel disease.

Colon cancer affects more than 150 000 people in the United States yearly and is a common malignancy in the elderly. It is usually slow growing and indolent and may not cause any symptoms or may come to attention only when slow bleeding has resulted in anemia, with consequent weakness, pallor, shortness of breath, angina, or dizziness. Other patients may develop signs and symptoms of large intestinal obstruction. The prognosis for a patient with colon cancer depends largely on the size and extent of spread through the body of the tumor at the time it is detected. Most colon cancer develops from polyps, and removal of precancerous polyps prevents cancer from developing. Thus, detection of polyps is important; hence the rationale for screening with colonoscopy beginning at age 50.

The Liver

Structural and functional changes occur in the liver with aging, and these may affect the manifestations of liver disease in the elderly. There is a progressive decrease in liver weight with senescence; it becomes more fatty; its ability to fight infection and metabolize drugs often diminishes; and blood flow to the liver is decreased. The spectrum and outcome of infectious and inflammatory liver disorders in the elderly appear to be different from those of younger people. For example, acute viral hepatitis due to hepatitis A and chronic viral hepatitis are seen less often in older patients but have a worse prognosis; disorders related to side effects of drugs are more common.

Liver dysfunction may be acute or chronic. The most common type of hepatitis in the elderly results from toxic agents such as medications, in contrast to hepatitis in the young, which is usually viral. Considering the frequency with which medications are prescribed, associated liver dysfunction is surprisingly rare but nonetheless represents an important problem; medications are estimated to cause up to 20% of cases of jaundice seen in elderly patients and are responsible for 25% of the cases of liver failure reported each year in the United States. Drugs frequently associated with liver inflammation include antibiotics, anesthetics, antihypertensives, and corticosteroids. Viral hepatitis is a more severe disease after the age of 60, with a higher incidence of progression to liver failure and coma and an increased mortality rate. Alcohol-induced liver damage remains a major problem worldwide, and the elderly are not exempt from the effects of this social toxin. Alcohol causes increased fat in the liver and may cause hepatitis and ultimately cirrhosis, but the course of alcoholic liver disease appears to be similar for both the young and the old. Liver dysfunction, with resultant jaundice, may occur in the setting of a severe systemic infection, in the postoperative patient, and with obstruction to the flow of bile from the liver to the intestine due to gallstones and tumors of the pancreas, bile ducts, and gallbladder. Finally, the liver may become swollen, and blood tests of liver function may be abnormal with congestive heart failure; these changes in the liver, even when severe, may show nearly complete reversal if the heart failure is controlled and improved.

Chronic liver disease is characterized by ongoing liver cell degeneration leading to scarring (i.e., fibrosis and cirrhosis). The cirrhotic process appears mostly the same in the elderly as in the young; it is often clinically silent and progresses without producing symptoms for many years. Once hepatic scarring has occurred, alterations in liver architecture are irreversible, and other systemic changes such as portal hypertension (hypertension within the internal vascular system) may follow. Causes of chronic liver disease include repeated acute insults with toxins such as alcohol, chronic obstruction of the bile ducts as in strictures (narrowings), iron overload, persistence of viral infections such as hepatitis B, C, and D, and

autoimmune hepatitis. Sometimes the etiology of chronic liver disease and cirrhosis is unknown and is referred to as cryptogenic. Cirrhosis from any cause may lead to the development of primary liver cancer; the liver also is the most frequent site of spread of cancer from other parts of the body. Finally, the liver may be involved in systemic illness, for example, in the fatty infiltration seen with diabetes mellitus. Such fatty change may result in slightly abnormal blood tests of liver function but rarely is clinically significant.

Gallbladder

More than 16 million Americans, or approximately 7% of the US population, have gallstones. Three hundred and fifty thousand cholecystectomies are performed annually, and hospital and related expenses total over $1 billion yearly.

The presence of gallstones (cholelithiasis) increases with advancing age such that about 30% of the population older than 65 years has gallstones. There is a female to male preponderance in the ratio of 3:1. In general, gallstones are composed primarily of cholesterol, which collects over a small focus of bilirubin, bile acids, or calcium. The stones form when bile, which is produced in the liver and stored in the gallbladder, becomes saturated with cholesterol. This is followed by the formation of a crystal, on which further precipitation of cholesterol occurs, causing the gallstone to grow.

Gallstones may be asymptomatic or they may give rise to inflammation in the gallbladder. Such inflammation, termed cholecystitis, may be either acute or chronic. Gallstones also may block the common bile duct, the tube that delivers bile from the liver to the intestine. Such blockage results in jaundice and infection, termed acute cholangitis. A syndrome seen primarily in the elderly, particularly in males, is cholecystitis without gallstones, called acalculous cholecystitis. This tends to occur in the setting of a coexistent serious illness, or perhaps after recent major surgery or severe trauma, when the patient is not allowed food by mouth for a prolonged period and the gallbladder is at rest.

Cancer of the gallbladder, a disease that favors elderly women, is associated with gallstones in 70–90% of cases. Unfortunately, it is rarely curable when diagnosed, even when it is found fortuitously at the time of gallbladder removal for other reasons.

The Pancreas

Inflammation of the pancreas, or pancreatitis, may be acute or chronic. Acute pancreatitis is usually related to gallstone disease or to alcohol ingestion; gallstones are more likely to be the problem in the elderly. Many commonly prescribed medications, including corticosteroids, certain antibiotics, and diuretics, also cause pancreatitis. Pancreatitis presents with significant abdominal pain and vomiting and can be diagnosed by blood tests (serum amylase and lipase) or a variety of imaging studies (ultrasound, computed tomography scan). The vast majority of attacks resolve, but some may lead to fulminant disease and death.

Chronic pancreatitis is often the result of repeated insults with a toxin, usually alcohol. In chronic pancreatitis there is ultimately calcification, fibrosis, and atrophy of the pancreas. Pancreatic function may be lost, and since pancreatic enzymes are responsible for a significant portion of nutrient digestion, there may be maldigestion of fats, carbohydrates, and protein. Patients with chronic pancreatitis frequently have severe abdominal pain, greasy foul-smelling stools, and diabetes. An association has been shown between chronic pancreatitis and pancreatic cancer.

Cancer of the pancreas is unfortunately a relatively common neoplasm. The incidence is higher in males, and there is a strong correlation with advancing age. These tumors usually are found when they obstruct the outflow of bile from the liver and thereby cause jaundice. Weight loss is common. When discovered in a person with jaundice and weight loss, these tumors are usually not suitable for an attempt at a surgical cure; only palliative and supportive therapy can be offered. Even when found during evaluation for an unrelated problem, cancer of the pancreas has a dismal prognosis.

Conclusion

Proper gastrointestinal function is vital, because it is only through normal digestion, absorption, and motility that adequate nutrition may be maintained. Gastrointestinal dysfunction is frequent in the elderly, however, and often different from that in younger populations. An understanding of the usual changes in function and dysfunction that accompany aging is important; the range of dysfunction in the elderly is broad, and making a correct diagnosis is often challenging.

See also: Cancer and Age; Diet and Nutrition.

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Gender Roles

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Glossary

Gender – Distinctions between masculinity and femininity.

Gender Relations – Dynamic, socially constructed power relations based on gender. Gender relations are embedded in social organization and interaction and have consequences for life chances.

Gender Roles – The sets of connected behaviors expected of women and men in specific situations.

Introduction

Research on gender and aging has progressed through several stages over the last few decades, and while each phase has emerged from the previous, all can be found in contemporary theory and research. Early work pointed to the contradiction between the preponderance of women in later life and their relative neglect by researchers. In the 1980s, scholars began to include old women in research more frequently, but this was accomplished in an 'add and stir' fashion that brought women into models derived from the study of men. Gender remained an individual, demographic attribute without theoretical explanation.

Feminist scholars focused on women's experiences as women described them and theorized that gender was a structural relation between groups. That is, when research begins with women's experiences, we see how their experiences differ from and are linked to men's. We come to realize that there is not one (male) model of retirement and that the retirement experiences of men and women each shape the other.

While gender relations disadvantage women in many of these areas, gender roles also provide women benefits that old men do not possess. For instance, old women are more likely to be widowed and living alone than men; because of gender relations in the family and work realms, they are also more likely to have lower incomes in old age, especially after the death of a spouse. These same gender roles also mean that women have more extensive social networks than men and are less dependent upon spouses for social integration or the performance of daily tasks. This broad approach frames this discussion of gender roles in later life, as well as why men and women might experience similar situations, including those related to financial status, retirement, caregiving, marital status and roles, and living arrangements, in different ways.

Gender Relations and Later Life

Gender

Research on gender roles and aging involves viewing maleness and femaleness as more than demographic or ascribed characteristics. It begins by distinguishing between sex – biological differences between males and females – and gender – cultural distinctions between masculinity and femininity. Gender is not a biological given, but is what people collectively agree that sex attributes mean. Societies construct men and women differently, and those differences reflect and perpetuate inequalities. To understand these inequities, scholars focus on gender relations: dynamic, constructed power relations embedded in social processes and institutionalized in social arenas, with

consequences for life chances. As a concept, gender relations emphasizes that gender serves as a social organizing principle and that men and women gain identities and power in relation to one another. Because they result from social interaction, gender relations are dynamic. What is considered masculine and feminine varies by culture, by time, and across groups within cultures – including age cohorts. This translation of sex into gender shapes men's and women's experiences across the life course and into old age.

Gender is embedded in social relationships at all levels, from individual interactions and identities to institutional processes. Societies organize on the basis of gender such that what is taken to be masculine and feminine influences and reflects a division of labor, the performance of which is evaluated and rewarded in a differential fashion. Thus, the gender identities that emerge in social interaction also serve to privilege men – give them an unearned advantage – while they usually disadvantage women, even as people resist and reformulate seemingly natural gender differences and meanings.

Gender relations are systematic, embedded in patterns of behavior such that they are taken for granted as simply the way things (i.e., families, jobs) work or the way things are. Thus, even though individuals enact them, gender relations are not dependent upon any one individual's actions or intentions, and they are often invisible. Because men's privileges are intimately tied to women's disadvantages, the situation of one group cannot be understood without at least implicit reference to the position of the other.

Gender relations underlie gender roles – behaviors that are expected of men and women in institutional situations (such as family, work, public, recreational, and other settings), based on their gender. Gender roles are upheld by ideologies (systems of beliefs) that justify the appropriateness of these behaviors. As one example, we relegate care tasks to women in a variety of situations, whether they involve physical activities such as cooking and cleaning or emotional carework. Women are the ones who should provide care within families (gender role) because they are, by their nature, more nurturing (ideology). Because we assume that girls are more nurturing than boys, we give girls dolls but give boys trucks. Then, when they grow up to emulate these beliefs and develop divergent skills, we take that as evidence that these differences are natural and that men's privileges in the family and work spheres are somehow more deserved. Further, because carework is natural and is performed out of love (ideology), it need not be remunerated. Women are segregated in carework professions and are paid less than men in positions of comparable worth for these reasons. The relatively low pay renders many women dependent on male breadwinners. The ability of men as a group to be breadwinners (gender role), to compete with other men for status and wealth and make significant wages, also rests upon the often invisible, unpaid carework and reproductive labor provided by women in family homes (gender role) out of love. Because these gender relations are embedded in the structures and collective beliefs of families, they do not depend upon any individual's intentions.

Gender Relations and Aging

While we can explore gender roles in a variety of institutions, their impacts on old age are most easily documented in the domestic sphere and the workplace. People engage in a wide range of activities that have economic value, whether or not they are paid. Which group is assigned which activities shapes both the composition and amount of resources available to them. For example, even though most women work for pay, they still bear primary responsibility for domestic labor, in part because no one else will do it and in part because of gender ideology; it is both women's work and one way they demonstrate their womanhood. Men can rely upon this labor, which enables them to better pursue their roles as breadwinners. Men's privilege within families is invisible and it translates into retirement privileges.

Recognizing that men's power is linked to women's subordination does not translate into straightforward or simple predictions about how gender influences the life course and old age. Instead, both gender positions carry with them opportunities and constraints, though it is certainly still true that, overall, men are more privileged. Gender is also linked with other hierarchies – such as race, ethnicity, sexuality, and class – in which the privilege of one group is tied, intentionally or not, to the oppression of others. These inequalities are not additive but intersect, as people experience the various relations that govern their lives simultaneously, not one at a time.

Age relations also constitute an axis of inequality, and thus old age disadvantages both men and women. As a result, even the most privileged older men will be disadvantaged relative to their younger counterparts. For example, ideologies regarding gender intersect with ageism such that men and women will attempt to preserve their youthful looks and thus not be excluded from social life. However, when and how this occurs varies by gender. Women are subject to a double standard of aging such that

they are viewed as old sooner than men. To a great extent, and despite women's inroads into the public realm, this results from the ideological equation of women's value with their attractiveness to men. Because such attractiveness is also equated with youth, an age component inheres; women are attractive to the extent that they also appear to be young. Much of the privilege of heterosexual womanhood is related to being White, in that White men of means seldom marry women of other racial groups. They also tend to marry much younger women.

For men, attractiveness to the opposite sex is a less important source of esteem than demonstrating that they can still perform in later life. To achieve status, women have had to align with powerful men, but men have had to compete with other men for status and wealth. While the essence of femininity may be about being, masculinity is about doing – performing. In this sense, ageist notions of masculinity and femininity influence the ways that both men and women experience later life as they strive to conform to gender roles and ideologies.

Table 1 Sex ratios (males per 100 females) of persons aged 65 and over, 2000: United States

Age	*Sex ratio*
65 and over	70.0
65 to 69	85.7
70 to 74	78.8
75 to 79	69.6
80 to 84	59.0
85 and over	40.7

Source: US Census Bureau, Census 2000 Summary File 1 (SF 1) 100 Percent Data, http://factfinder.census.gov; accessed May 25, 2005.

Demographic Characteristics

The increased interest in women's aging experiences was partly spurred by the demographic reality that most old persons are women. **Table 1** shows that, in the United States, about 59% of those over age 65 are women. Put differently, there are 70 men for every 100 similarly aged woman. By age 85, this sex ratio is even more skewed; women comprise 71% of persons this age and older, and there are only about 41 men for every 100 women. This gender difference in life expectancy is reflected in **Table 2**.

Regardless of race or ethnicity, women outlive men at all ages. Thus, even though the race-based discrepancy slowly decreases with age, narrowing at age 65 and reversing by age 85, women consistently outlive men. Further, as evidenced by projections, this female advantage is not anticipated to decrease in the near future.

Not surprisingly, the gender composition of old people in the United States influences men's and women's marital patterns. As can be seen from **Table 3**, men are much more likely than women to be married in old age. Seven in ten (71%) men but only

Table 2 Life expectancy by age and race, 2001, 2010, and 2040 (projected), United States

Age	*Total*		*Women*		*Men*	
	White	*Black*	*White*	*Black*	*White*	*Black*
Birth	77.7	72.2	80.2	75.5	75.0	68.6
–2010	79	74.5	81.8	77.8	76.1	70.9
Age 65	18.2	16.4	19.5	17.9	16.5	14.4
–2040	Not available	Not available	22.0	Not available	19.0	Not available
Age 80	Not available	Not available	9.3	9.2	7.7	7.3
Age 85	6.4	6.7	6.7	7.0	5.6	5.7

Sources: Federal Interagency Forum on Aging Related Statistics, 2004, Older Americans 2004: Key Indicators of Well-Being, Washington, DC: US Government Printing Office; US Bureau of the Census, Statistical Abstracts of the United States: 2004–2005, Washington, DC: US Government Printing Office; Metlife Mature Market Institute, 2005, Demographic Profile of 65 + Population, http://www.metlife.com; accessed May 27, 2005.

Table 3 Marital status among men and women aged 65 and over in the United States, 2003

Marital status	*Men (%)*				*Women (%)*			
	65 and over	*65–74*	*75–84*	*85 and over*	*65 and over*	*65–74*	*75–84*	*85 and over*
Married, spouse present	71.2	74.4	69.8	56.1	41.1	53.5	33.7	12.5
Widowed	14.3	8.8	18.4	34.6	44.3	29.4	53.3	78.3
Divorced/separated/spouse absent	10.2	12.3	7.7	6.5	10.9	13.8	9.2	4.9
Never married	4.3	4.6	4.1	2.8	3.7	3.4	3.8	4.2

Source: US Bureau of the Census, March 2003 Current Population Survey, http://www.census.gov; accessed June 4, 2005.

Table 4 Living arrangements of men and women aged 65 and over, by race[a] and Hispanic origin, in the United States, 2003

	With spouse (%)	*With other relatives (%)*	*With nonrelatives (%)*	*Alone (%)*
Men				
Total	71.2	7.1	3.0	18.8
Non-Hispanic White	72.9	5.7	2.7	18.7
Black	56.6	9.5	4.3	29.5
Asian	68.5	22.5	0.5	8.3
Hispanic (of any race)	68.7	14.4	4.7	12.0
Women				
Total	41.1	17.4	1.8	39.7
Non-Hispanic White	42.9	13.6	1.7	41.8
Black	25.4	33.5	2.1	39.0
Asian	42.6	35.8	2.2	19.4
Hispanic (of any race)	39.9	36.0	2.2	21.9

Source: http://www.agingstats.gov.
[a]The racial categories reported here reflect those who selected single races only, and as compiled by the US Census.

four in ten (41%) women over age 65 are presently married. Instead, old women are most likely to be widowed (44.3%). By contrast, only 14.3% of men are widowed.

Of course, the proportions of men and women in these two marital statuses are related to age. Most people in the 65–75 age group, regardless of gender, are married. Men's likelihood of being widowed increases with age, but even in the 85+ group, more than half (56.1%) of men are married, while relatively few women of that age (12.5%) are.

These gender differences result both from the fact that women outlive men, on average, and from the social norms that dictate that men marry women younger than themselves. The differences in life expectancies mean that, once widowed in later life, it is more difficult for women to remarry.

Old men and women are about equally likely to be divorced, but the percentage within each gender declines with older age groups. This probably reflects different norms concerning the acceptability of divorce across these cohorts rather than differences in propensity to remarry. Regardless of gender, the never-married group is similar and consistent across age groups. Gender patterns in living arrangements in later life reflect those of marital status; thus, as **Table 4** reveals, old men are more likely to live with a spouse than old women. From another vantage, we see that older women are twice as likely to live alone as old men.

At the same time, gender patterns in living arrangements when not with a spouse vary by race and ethnicity. Generally speaking, minority group members are more likely to live with other relatives than to live alone (Black men are the lone exception), whereas White men and women are more likely to live alone. While these racial and ethnic patterns may reflect cultural differences, living alone requires some level of financial ability. Given the poorer financial position of minority women in particular (see the following section), it likely that economics plays a major role in these living arrangements.

Because widowhood rates increase with age, so too does the tendency for old men and women to live alone. Only 30% of women aged 65–74 live alone, compared to half of those over 75; similar, though smaller, differences accrue among men. Living alone has also risen over time; more men and women over age 75 live alone today (22.9 and 49.8%, respectively) than in 1970 (19.1 and 37%, respectively). This increase reflects the better health and finances of today's older cohorts and the desire to maintain autonomy.

Marital status and living arrangements influence gender roles to the extent that they shape roles available to older adults. Certainly, old men are more likely than old women to continue their marital roles, but the preponderance of married men also means that wives are more likely than husbands to serve as spousal caregivers. The preponderance of older Asians and Hispanics who live with others means that these groups are more likely to take on daily grandparenting roles than Whites and, to a lesser degree, Blacks. Old women are particularly likely to maintain their gender roles in such circumstances, as grandmothers are often called upon to provide child care and other forms of domestic labor.

Economic Security

Financial security is shaped by and influences gender roles across the life course and into old age. The expectations that men will focus on careers and the workplace and women will engage in reproductive labor as primary roles have important implications for financial status in later life. Although the median

income for those aged 65 and over is $14 664, this figure hides gender disparities. In 2003, the median income for old women, $11 854, was just 58% of men's median income, $20 363. In 2003, the US poverty threshold for an elderly individual was $8825, and 10.2% (about 3.6 million old persons) fell below this line. Old women were more likely to fall below this threshold (12.5%) than older men (7.3%).

Those who live alone are more likely to be poor: 18.6% compared to 5.8% of those living with families. However, women are even more vulnerable. In 2002, 15.6% of older men and 20.5% of older women who lived alone were poor, compared to only about 5% of married men and women. In addition, race and ethnic differences are such that non-Hispanic Whites (men and women) have the lowest poverty rates among those who live alone. In fact, Black and Hispanic men living alone have higher poverty rates (30.2 and 37.2%, respectively) than do non-Hispanic White women (17.4%). Minority women are the most disadvantaged; 45% or more of African American and Hispanic women who live alone are poor. In this sense, it is not only that two incomes can lift old persons out of poverty, but also that a man's income, to the extent that he is privileged by race and class, is more likely to be critical.

Sources of Income

Old women's greater economic vulnerability results from the fact that the sources of income in old age are gendered in terms of access and amounts. In the United States, the four main sources of income for those over 65 include Social Security, private pensions, earnings, and assets. In 2002, Social Security provided 39% of income; earnings, 25%; pensions, 19%; and assets, 14%.

Table 5 shows the importance of each of these sources to men and women's income security. (In reviewing these figures, note that they do not differentiate whether income received is based on an individual's or a spouse's work history. This results in inflated figures for women, who are more likely than men to receive income due to their spouse's work history, and provides higher figures than those reported later in this article.)

Though men and women enjoy similar access to both Social Security and asset income, they diverge in relation to private pension receipt and earnings. Men receive more income from each source, with the exception of assets. Women's median income from Social Security is 70% of men's, and they receive just over half of what men receive from private pensions. Wages received from employment do not diverge significantly from the inequalities experienced by younger women, except that in old age the gender gap is larger: women earn only 57% of what men receive. And although women get 81% of what men receive in asset income, this source of revenue is by far the least important, adding less than $1700 a year to men's or women's annual income.

A closer look at some of these sources demonstrates how gender relations shape men's and women's access to each and helps explain why old women have lower incomes and a greater likelihood of poverty.

Social Security Social Security is the most important source of income for most old people in the United States. It provides more than half of all income received for two-thirds of old people and almost half of the income received for four-fifths. Even more, it comprises 90% or more of all income for a full one-third of elderly people, and 100% of income for more than one-fifth (22%). Reliance on Social Security benefits is thus high for all but the richest quintile of old people, whose earnings and pensions add more income than Social Security.

Still, as **Table 5** makes clear, women receive less income from Social Security than men. These differences accrue even among those who collect benefits based on their own work histories: in 2003, monthly Social Security payments for retired workers averaged $1039 for men and $798 for women.

Table 5 Sources of income among men and women aged 65 and over in the United States, 2000

Sources of income	*Percent receiving income from source*		*Median income received*[a]		*Gender gap (women/men)*
	Men	*Women*	*Men*	*Women*	
Social Security	88.5	90.3	$11 040	$7750	70
Private pensions	46.7	29.5	$10 340	$5600	54
Assets	64.8	60.0	$1650	$1330	81
Earnings	22.4	12.3	$14 780	$8450	57

Source: Lee S and Shaw L (2003) *Gender and Economic Security in Retirement.* Washington, D.C.: Institute for Women's Policy Research.

[a]The median income figures are based on those who receive these sources of income only. Thus, the totals for these columns are higher than the median incomes of men and women, as many old persons do not receive income from each of these sources.

Gender inequalities in paid and unpaid labor are embedded in the Social Security program. Based on men's experiences of paid work and on a traditional model of the family, Social Security reinforces the gender differences contained in both domains. The original Social Security legislation covered only retired workers, as it assumed a form of gender relations wherein women always depend upon men in heterosexual (marital) relationships, and that women would be homemakers and men would be breadwinners. Because this legislation assumed a patriarchal family head who would provide for other members, men's presumed labor force history – a long-term, stable career with ever-increasing rewards – formed the basis of benefit eligibility and calculations. Thus, earnings levels and continuous employment are key to overall benefit levels, as are long-term marital bonds.

The inequities of these gender role assumptions become apparent when we examine how they translate into retirement income. First, a wife's benefit eligibility is based on marital status and the assumption that her job is to do domestic work. While such reproductive labor is implicitly acknowledged as underlying a husband's ability to work for money, it is still valued at half the level of his: a dependent spouse is entitled to only 50% of the breadwinner's benefit.

Second, the domestic division of labor influences retirement in terms of both the jobs that people take and their upward mobility. Among today's retirees, women often entered the labor force later than men, had to work particular shifts, turn down promotions, or enter particular types of jobs in order to maintain their domestic labor roles. Domestic labor time also has a negative impact on earnings. By contrast, this division of labor privileges men. In addition to higher pay levels, White, middle-class men can move into a more time-consuming position or to a different city, well-supported by their wives' unpaid work at home.

The calculation of retired worker benefits also reflects unequal gender roles. First, benefit levels are tied to earnings, such that the more a person earns, the greater the likelihood that the person will receive the maximum benefit ($1825 per month in 2004). However, on average, women receive lower wages than men across the life course, even when they work continuously. Not only do women tend to be clustered in low-paying jobs, but even when women and men are employed within the same occupations, women earn less. Such wage disparities are cumulative, influencing not only Social Security benefits but also women's ability to accrue wealth in other ways. The extent to which this labor market situation will change with younger cohorts is not clear. Although the gender gap in earnings is smaller among younger age groups, the differential remains significant and grows as these cohorts age, which might explain why, as a group, women's wages have stood at about 75% of men's for more than a decade.

Second, benefits are based on the earnings of the best 35 years of work, and, due to family obligations, women are far more likely than men to have worked fewer than 35 years and thus have years of zero earnings included in the equation. Thus, women who leave the labor market usually receive less pay upon their return and lower benefits later on, while men maintain their earnings and reduce the chance of having zero-pay years.

Finally, because Social Security legislation assumed only one breadwinner and tied benefits to wage levels, it ignored women workers from the start. As a result, couples with one (usually male) high-wage earner can receive higher benefits than couples with a similar household income that results from the paid labor of both spouses. Thus, gender roles shape retirement income in many ways. The assumption of a male breadwinner has served to justify women's lower wages and mobility, which in turn further justifies women's predominance in carework and other domestic obligations. Both women's and men's retirement income is firmly rooted in the gender division of labor.

Private Pensions Only about 50% of all workers have pension coverage on their current jobs. Further, defined benefit pension rules often have been based on assumptions similar to those embedded in Social Security, mandating continuous labor force participation and rewarding those with the highest wages. As a result, women's reproductive labor can preclude pension eligibility, and their work in lower-waged jobs, based on various gender role constraints discussed previously, leaves them with lower pension benefits.

The dramatic shift in type of pension coverage, from defined benefit to defined contribution plans, over the last 20 years presents additional problems for women as members of a lower-waged work force. To be sure, this change has meant that more women have access to private pensions, and by 2002, the gender gap in coverage among those aged 45–64 years of age had almost disappeared, with 51.7% of women and 55% of men reporting pension plan coverage. However, defined contribution most benefits those with high earnings, who tend to be White, middle-class men who can set more money aside. But they present drawbacks for lower-waged employees, who tend to be women. First, while employers may contribute to such plans, they often do not. For their part, low-waged workers do not have

enough expendable income to contribute much to their pension (and in some instances, are not required to do so). Thus, the amounts put into their pensions accumulate more slowly. Further, workers and not employers bear the risk of these plans. However, low-waged workers are less likely than their higher-paid counterparts to have the financial savvy to invest this money wisely, or to have the money to hire a consultant. And even with the best of advice, market changes are outside individuals' control. Finally, low-waged workers are those most likely to withdraw money from their pension, even while paying a stiff penalty, for family emergencies.

Thus, private pensions incorporate gender relations in the division of labor in several ways that penalize women for their reproductive labor, their segregation in particular jobs, and their lower level of pay. Women are less likely than men to collect pensions in jobs that do have such coverage, and, when they do receive pensions, the amounts are much smaller than men receive.

Retirement Experiences

The discussion of finances in later life illustrates one way that gender roles shape retirement. They also shape its meaning. For instance, although men and women both tend to talk about retirement as freedom, they diverge in terms of what this freedom entails. Many people regard retirement as a time of leisure. But many women, men of color, and members of the working class must continue to earn money, in both the formal and informal economy, and women continue their unpaid labor in the home. By contrast, more privileged men have the choice of whether to engage in paid work or domestic labor. The voluntary nature of these activities for them underscores the power differences based on gender, as well as race and class.

When women retire from the labor market, they feel freer because they have reduced their double burden. They maintain responsibility for domestic tasks but can now accomplish them in a more leisurely fashion than before. And while some retired men take on domestic chores, they generally do not take primary responsibility nor do as much as most women. In this sense, then, domestic labor is part of the retirement experiences of both women and men. While a woman's retirement is often characterized by continued domestic labor, married men's freedom to enjoy leisure time in retirement or choose to help with domestic labor is tied to wives' responsibility for the same.

Class and race matter in this regard. Women of higher class, the vast majority of whom are White, may maintain responsibility for domestic labor but can pay other women – working-class and often women of color – to do it. The labor market disadvantages of working-class White men and men of color may also preclude a leisurely retirement. The low rates of racial intermarriage, especially between Blacks and Whites, prevent most women of color from enjoying the privileges of heterosexual White womanhood – attachment to a high-earning man.

Some of those who collect retirement benefits return to paid labor as well. As can be seen in **Table 6**, labor force participation rates of pre-retirees have moved in opposite directions by gender, reflecting aspects of gender relations at home and at work.

When Social Security provisions were changed during the 1960s to allow the collection of reduced benefits at age 62, men were more likely to be employed in occupations that enabled the accumulation of wealth or pension funding that would allow them to retire earlier than age 65. At the same time, women – particularly White, middle-class, married women – began entering the labor force in unprecedented numbers. Subsequent cohorts have

Table 6 US labor force participation rates (percent), age 55 and over, by gender, 1963–2003

Year	*Men*				*Women*			
	55–61	*62–64*	*65–69*	*70+*	*55–61*	*62–64*	*65–69*	*70+*
1963	89.9	75.8	40.9	20.8	43.7	28.8	16.5	5.9
1965	88.8	73.2	43.0	19.1	45.3	29.5	17.4	6.1
1970	87.7	69.4	41.6	17.6	47.0	32.3	17.3	5.7
1975	81.9	58.6	31.7	15.0	45.6	28.9	14.5	4.8
1980	79.1	52.6	28.5	13.1	46.1	28.5	15.1	4.5
1985	76.6	46.1	24.4	10.5	47.4	28.7	13.5	4.3
1990	76.7	46.5	26.0	10.7	51.7	30.7	17.0	4.7
2000	74.3	47.0	30.3	12.0	58.3	34.1	19.5	5.8
2003	74.9	49.6	32.8	12.3	62.5	38.6	22.7	6.4

Source: Federal Interagency Forum on Aging Related Statistics (2004) *Older Americans 2004: Key Indicators of Well-Being* (Table 11). Washington, DC: US Government Printing Office.

followed suit, spurred both by the women's rights movement and the economic necessity created by declines in the value of men's wages. These cohorts have swelled the labor force participation rates of older women as they aged. The continued need for two incomes and the greater acceptance of and opportunities for women's labor force participation (particularly in the low-waged service sector) mean that the gender gap in paid employment rates has narrowed at all ages. Indeed, in 2003, the labor force participation rate among those aged 55–61 differed by only 12% by gender, compared to a 46% difference four decades earlier.

Still, the percentages of men and women over age 65 in the labor force have been increasing since the 1980s. In 2003, 33% of men and 23% of women aged 65–69 were in the labor force. Gender roles influence decisions to remain in or re-enter the labor force, as well as the jobs old people seek. Such labor force engagement appears to be bimodal. Some continue to work as high-paid consultants, but a large number remain in low-paid, usually service jobs. White professional men are more likely to be in the former group, whereas women (as well as working-class men and men of color) fall into the latter. While both groups may work to sustain a lifestyle or simply to work, the latter group is far more likely to work out of financial necessity. Given the lower wages that women receive prior to retirement – women aged 50–64 earn about 64% of what men earn – they are far more likely to feel they must work. That they receive low wages in old age as well is reflected in the earnings reported in **Table 5**. Women's continued work in retirement, paid or unpaid, is not freely chosen when it is predicated on financial need that results from gender relations within the family and workplace.

Carework

Throughout the life course, carework – an activity that involves both the practical caring for and the emotional caring about – tends to be women's work. Women do the overwhelming majority of primary caregiving in all racial and ethnic groups, regardless of employment status. When both women and men perform carework, tasks tend to be gendered. Women engage in more personal care tasks and men focus on the instrumental. This reflects the broader divisions in domestic labor, in which women perform the more personal, bodily, indoor, and daily labor and men do more periodic and outdoor tasks.

However, these generalizations reflect all caregivers and caregiving relationships. Among older people, spouses are the preferred caregivers. Because women tend to marry men older than themselves and because those men have lower life expectancies, men are usually the recipients, not givers, of spousal care. But when spousal caregivers are compared, there are few of the gender differences reported previously. Husbands and wives spend about the same amount of time giving care and perform similar tasks. In the United States, where few public options other than family care exist, husbands are as likely as wives to engage in personal care, such as bathing and toileting, for their spouses.

Some scholars suggest that men who give care (regardless of their relationship with the care recipient) may handle it better. Caregiving women appear to report more stress, anxiety, depression, and physical problems than caregiving men. Because of their gender roles, scholars suggest, men approach caregiving more as a job – a series of tasks to be done and mastered – than as a matter of their identity as men. They may focus more on the caring for aspects, separating them from the caring about. They may be less emotionally involved and better able to take time for themselves, leading some researchers to suggest that men may 'care better by caring less.'

However, it remains unclear whether men suffer less stress than women. In line with the gender role dictates of stoicism, we know that men generally report stress and depression to physicians less readily than women. They may express stress in ways not tapped by research that has traditionally focused more on women, and qualitative research suggests that caregiving men talk about stress in different terms. In any case, preliminary research suggests that, based on gender roles, both the approach to caregiving and the outcomes are gendered. The fact that women perform most domestic labor tasks and build expectations of nurturing behavior into their identities means that women will be more used to performing some daily tasks and will maintain higher expectations of their caregiving that more quickly lead to stress. By contrast, men may indeed approach carework in a more managerial fashion, and while they may find learning new tasks stressful, they may also garner a sense of accomplishment in their daily tasks. Being nurturing is not an essential part of masculinity, so failure to gain compliance from a care recipient, or calm her down, for instance, does not violate a man's sense of self in the way that might occur among women.

Finally, a critical aspect of the level of stress – or reward – experienced in caregiving has to do with how care is received. While sparse, research points to the importance of marital gender relations in understanding how care-receiving spouses shape caregivers' experiences. Because women typically perform domestic labor, they understand as care recipients what

their husbands do for them and are likely to express gratitude. By contrast, care-receiving husbands have no such referent. The more that men must depend on their wives, the more that they may feel their masculine autonomy threatened. As a result, they can become more demanding and controlling. Thus, the power relations that characterize their marriages and give the husbands control may not cease when husbands become dependent upon wives for care, and caregiving wives still can feel constraints upon their time and decision making.

Marital Status and Gender Relations

Marital status structures the entire adult life course and influences psychological and physical well-being for both men and women. Although not all marriages are happy, being married usually ensures a companion, and older married persons express greater happiness than those who are unmarried.

At the same time, marriage tends to have greater positive effects for men than for women. Aside from the benefits that companionship itself brings, the gender relations in marriage also influence older men and women in particular ways. Being married provides financial security for older people, especially for women, given the greater income that men generate. And while being married enhances physical health, this is partly because spouses encourage healthier behavior. In this regard, women's caretaking roles make them most likely to engage in self-care and more likely to encourage healthy behaviors in husbands, in terms of lifestyles and listening to doctors.

Women's caretaking roles matter in other respects as well. Not only do women do more emotional labor in families and with their spouses, but they also are the kin-keepers in marriages, maintaining contact with children and other relatives as well as friends. As a result, husbands rely on wives as confidents more exclusively than vice versa. In short, while marriage provides benefits for both old men and women, women's domestic labor – which involves both physical and emotional work – keeps husbands integrated and healthier. Research finds that, compared to widowed, divorced, and never-married men, married men have the greatest levels of social interaction both within and outside the home.

Widowhood presents a specter of loneliness for men and women alike, and, as a result, widowed persons report lower levels of psychological well-being than married persons. That said, widowed men appear to report greater depression over time than women. This likely results from the different kinds of losses that husbands and wives experience, due to marital gender roles.

While gender relations over the life course make widows more vulnerable to poverty than widowers, they are also aware of the domestic labor that was required. For some, widowhood gives a new sort of freedom. Thus, many widows choose not to take on another burden of domestic and carework for a spouse. In addition, while women may also face the 'coupledom' that excludes single people, they usually have additional sources of support, including close bonds with their children. Women who want to maintain some of their new freedom while also having an intimate relationship may solve this quandary by enjoying a committed relationship while maintaining their own homes – an option increasingly popular in Europe.

By contrast, widowers must often learn how to do the work of daily living – both physically and emotionally. Domestic labor chores may fall entirely upon them, as does the kin-keeping and friendship maintenance. Their relative lack of domestic labor skills makes men more vulnerable to institutionalization in the 6 months following widowhood than women. Widowers who express disinterest in remarriage do so not to preserve autonomy, but because they realize their advanced age and poor health make them less marriageable.

Divorce combines the effects of widowerhood on older men with greater isolation. Strained relationships with children and the tendency to move after divorce can shatter their social networks. They tend to feel the most unhappy with their networks and report the most loneliness in old age. By contrast, and in keeping with marital roles, while divorced women often suffer financial hardships, they tend to have larger social networks and closer ties to children.

Conclusions

Men's and women's roles and experiences are linked. Understanding that widowhood inspires loneliness in women and men but may also present different challenges to them suggests more effective ways to help surviving spouses. Knowing that all caregivers suffer stress, but that the sources and expressions may differ, enhances our ability to intervene and offer support.

Not all men are privileged and not all women are disadvantaged. Gender relations intersect with other hierarchies such that White women, for example, might be better off than Black men in some realms. Some disadvantages can be sources of strength, just as struggling to maintain privileges can come at some costs. When we take a life course view, we can see, for instance, men's ability to garner authority and

wealth in the public sphere may render financial security in old age but may also hamper relationships and health, while women's caregiving roles may result in greater poverty but also greater support from informal networks.

Further research should show how gender intersects with other inequalities. Recent suggestions that men and women become more androgynous as they age – as well as research on this possibility – may well be based on models of femininity and masculinity more appropriate to younger ages. And some of what we know of the effects of gender roles and relations in younger years may not apply to old age. The burden of housework early in the life course weighs upon women in some ways but in later years may sustain their sense of femininity in ways that please them.

Social structures are not static; people resist and alter them as they live out their roles. Gender relations are dynamic; structural changes can be expected to influence experiences of gender and old age, just as the refashioning of gender identities will affect institutions such as families. Although women's greater labor force participation has not leveled the distribution of housework, men and women have changed their ideas about masculinity and femininity enough that men contribute more to child care. As a result, we can expect future cohorts to demonstrate somewhat divergent gender patterns in old age. At the same time, without substantial shifts in gender arrangements, inequalities between men and women will persist, although levels and expressions may change.

See also: Caregiving and Caring; Economics: Society; Life Course; Social Networks, Support, and Integration; Social Security.

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Generational Differences: Age-Period-Cohort

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Glossary

Cohort – Group of persons entering the environment at the same point or range in time.

Cross-Sectional Sequence – Groups of persons assessed once, where at least two age levels are sampled at a minimum of two different measurement occasions.

Longitudinal Sequence – At least two groups of persons assessed at least twice over the same age range.

Introduction

Generational differences are treated in this article from a psychological perspective, although attention

will be called to the historical context of the concept as it evolved in both sociology and psychology. Moreover, generations are differentiated from cohorts, and the article discusses the relevance of the literature on cohort differences to an understanding of generational differences. Methodological issues in the psychological study of generational differences and cohort differences will be considered, including an exposition of the age-cohort-period model. Examples of findings from the literature will draw largely on the Seattle Longitudinal Study, including findings on generational differences in cognitive performance, selected demographic characteristics, and perceptions of family environments.

Sociologists' and Psychologists' Views of Generations

The concept of generational differences received considerable play in the early twentieth century when the sociologist Karl Mannheim called attention to generational conflicts, particularly those between adolescents and young adults and their parents. Indeed, much of the sociological literature on generational differences deals with issues of generational conflicts and transmission of values. Similar early concerns in psychology appear in the work of Charlotte Buehler, centering on conflicts between adolescents and their parents. Among developmental psychologists, hints of concern about possible effects of generational differences can be found in the work of Raymond Kuhlen, who was the first in psychology to call attention to the fact that individuals age within the context of changing societies, implying the possibility that the timing of behavioral change might be important.

In the more recent literature, generational differences began to resurface in the mid-1960s almost simultaneously in both the sociological and developmental psychology literature. Ryder suggested that the notion of cohort progression was an essential concept for the sociological study of change. Riley, Johnson, and Foner further developed this theme in its implication for social gerontology in a seminal volume. At the same time, the author called attention to the fact that aging data obtained from cross-sectional and longitudinal data sets could not correspond, because cross-sectional age differences are confounded with cohort (generational) differences, while longitudinal age changes are confounded with time-of-measurement (period) differences. He specified a general developmental model that examined the formal nature of these relationships, placed them in the framework of quasi-experimental designs in psychology and education, and proposed strategies for collecting and analyzing data that might help obtain better estimates of the age factor.

Attempts to unconfound the age-period-cohort model have been controversial. However, given appropriate limiting assumptions, cohort studies have played an important role in behavioral research, not only in controlling for methodological artifacts that might result in the over- or underestimation of aging effects, but also in examining the contextual variables that affect levels of behavior and expression of personality traits over time. There is still a lack of good understanding of the relationship between macro-societal change and its effects upon age differences and age changes in behavior, but the study of generational differences in behavior has provided an initial attempt to identify those variables most prone to shifts across generations. Many geropsychologists who began prospective studies of aging in the 1960s have therefore included multiple cohort designs of one kind or another to deal with the issue of possible generational differences.

Generation and Cohort

The term generation often denotes successive groups in time in which the second group could (but need not necessarily be) the biological offspring of the first group. By contrast, the term cohort is an arbitrary definition of a point in time or range of time during which members of a group enter the environment (by birth or other temporal entry). Hence the temporal distance between two generations will generally represent a time frame from 20 to 30 years, while cohort differences may and often do cover much shorter periods of time.

Generational and cohort differences are usually studied in the context of groups of people (birth cohorts) entering the environment at the same point (or range) of calendar time. It should nevertheless be stressed that the temporal boundaries for generations could also be characterized by non-calendar definitions. For example, the initial group of workers hired for a new factory or the first faculty of a new educational institution would represent a generation (regardless of the individuals' calendar age), as would the initial membership of a newly formed club, persons called to active duty in the armed forces at the same point in time, or the first-time purchasers of homes in a new residential subdivision.

Methodological Issues

Research Designs for the Study of Generational Differences: The Age-Cohort-Period Model

The age-cohort-period model specifies that any age-related or time-dependent behavior can be assigned

three temporal characteristics, such that

$$b = f(A + C + P),$$

where b (behavior) is observed at the chronological age A, for individuals over the calendar period P who entered the environment as members of cohort C. This relationship is similar to the relationship among the physical variables of volume, pressure, and temperature. Here, also, the third component can always be stated as a function of the other two components. Thus,

$$A = C + P$$
$$C = A + P,$$

and

$$P = A + C.$$

Each of these three components may be of primary interest for some scientific questions in the developmental sciences, and it is therefore useful to be able to estimate the specific contribution attributable to each component. In the behavioral sciences, in particular, we typically want to differentiate effects that change across age (intraindividual change) from those effects that differ across cohorts or generations (interindividual differences). On the other hand, educational researchers might be more interested in differentiating changing educational impact across different periods from the ages of those affected.

Data Collection Strategies

Empirical studies in the developmental sciences involve age and/or cohort comparisons either at one point in time or at successive time intervals. Traditional strategies used for this purpose are represented by cross-sectional, longitudinal, and time-lag designs.

Cross-sectional strategy investigates the hypothesis that there are differences in one or more characteristics for samples drawn from different cohorts but measured at the same point in time. This strategy is most appropriate for the study of interindividual differences. Age differences in behavior at a particular point in historical time may be relevant for policy decisions that lead to differential societal responses regardless of the antecedent conditions responsible for the age differences. Age differences detected in a cross-sectional data set, however, are inextricably confounded with cohort differences. Since cross-sectional subsamples are measured only once, no information is available on intraindividual change. Unless there is independent evidence to suggest that older cohorts performed at the same level as younger cohorts at equivalent ages, it would be most parsimonious to assume, at least in comparisons of adult samples, that cross-sectional age differences represent estimates of cohort differences that may be either inflated or reduced by maturational changes occurring over a specified age range.

Longitudinal strategy investigates whether age-related changes have occurred within the same population cohort measured on two or more occasions. This strategy is appropriate when the investigator wishes to predict age differentiation in behavior that occurs over time. But longitudinal data do not always provide unambiguous estimates of intraindividual change. A single-cohort longitudinal study confounds age-related (maturational) change with period effects that are specific to the particular historical period over which the behavior is monitored. The period effects could either mask or grossly inflate estimates of maturational changes.

Time-lag strategy compares two or more samples of individuals drawn from successive cohorts at successive points in time at the same chronological age. The hypothesis tested is whether there are differences in a given behavior for samples of equal age but drawn at different points in time. This strategy is of interest to social and educational psychologists. It is particularly appropriate when one wishes to study performance of individuals of similar age in successive cohorts (e.g., comparing baby boomers with the preceding generation). The simple time-lag design confounds cohort effect with period effects and may provide inflated or reduced cohort estimates depending on whether the temporal interval between the cohorts represents a period of favorable or adverse environmental influences.

Sequential Strategies

Generational differences were seen as serious confounds in studies of human aging. Consequently, several alternative sequential strategies were introduced that might differentiate effects of maturation characteristic for a particular developmental period from the attainment of different levels of functioning attributable to differences in socialization and/or other life experiences characteristic for successive generations by assessing the behavior of more than one cohort over a given age range.

The term 'sequential' implies that the sampling strategy used to study generational differences must include the acquisition of a sequence of samples taken across several measurement occasions. Perhaps the most widely used sequential strategy is the cross-sequential design, in which two or more cohorts are followed over an identical time period. This

approach permits the direct comparison of longitudinal and cross-sectional data (provided that the calendar time ranges are similar for age and cohort). The advantage of this approach is that only two points in time are needed, hence the early appearance in the literature of studies using this design. For purposes of studying generational differences, however, this approach represents a 'model misspecification' because it does not allow the comparison of each cohort over the same age range.

As indicated previously, geropsychologists and other developmental scientists often find the cohort-sequential design of greatest interest because it explicitly differentiates intraindividual age changes that occur within a generation from interindividual differences between generations. This design also permits a check of the consistency of age functions over successive generations, thereby offering greater external validity than would be provided by a single-cohort longitudinal design. A cohort-sequential study consists of two or more generations (however defined) being followed over two or more similar age levels. The minimum design for such a study involves three measurement points, allowing each of two cohorts to be followed over the same age range.

Repeated Measures and Independent Samples

In a typical longitudinal study, repeated measures are taken of the same research participants at successive times. It is also possible, however, to use the same research design but with independent samples at each age level being measured. In this alternative design, one would draw a new (independent) sample from the same cohort initially tested. The independent sampling approach works well when a large sample is drawn from a large population, and when one is primarily interested in the estimation of population parameters. This approach controls for the effects of non-random dropout, regression to the mean because of fallible measurement instruments, and effects of practice or inadvertent changes in experimental protocols. If small samples are used, it is, of course, necessary to make sure that successive independent samples are matched on factors such as gender, income, and education to avoid possible differences due to selection biases.

Designs for Specific Issues in the Study of Generational Differences

If the primary interest of an investigator is the estimation of magnitudes of generational differences, then the independent samples approach described earlier will suffice. That is, one needs to obtain data from a minimum of two cohorts at the same age in order to estimate the magnitude of the cohort difference. However, it is probably quite problematic to estimate generational differences at only one age level, because of the possibility of age-by-cohort interactions. Hence, one would recommend for this purpose a cross-sectional sequence of sufficient temporal length that each pair of cohorts can be compared at multiple age levels, even though all cohort pairs cannot be compared at every age level of interest. When this is done, one can then set the performance of the earliest-born cohort as a base and cumulate successive cohort differences, in the same manner as life span psychologists estimate age gradients. This approach permits contrasting generational shifts in performance levels over time for distinct behavioral dimensions.

It should be noted that this approach would not suffice for the estimation of generational differences in rates of change. For this purpose it is necessary to follow the same individuals over time in the form of a longitudinal sequence that allows contrasting successive cohorts over the same age range. That approach is essential if one wishes to address the question of whether there have been any changes in the rate of aging for successive generations.

The study of differences in the behavior of successive generations of biologically related individuals requires contrasting parents with their adult offspring. Ideally, data should be available for parents and offspring at the same ages. Barring the availability of such ideal data, designs of studies involving differences within family units must pay attention to the age at which study participants are assessed, as well as to gender differences, when cross-gender parent–offspring pairs are studied. Adjustments for the confounding variables of age and gender must often be used to obtain realistic estimates of generational differences within biologically related family units.

Substantive Findings

The remainder of this article outlines what is currently known of generational differences in intellectual competence, selected demographic characteristics, and perceptions of family environments that may have implications for our understanding of behavioral aging; it relies heavily on findings from the Seattle Longitudinal Study.

Generational Differences in Cognitive Abilities

Generational differences were first studied by means of cohort-sequential designs as part of the analyses conducted for the third cycle of the Seattle Longitudinal Study (SLS). This study began in 1956

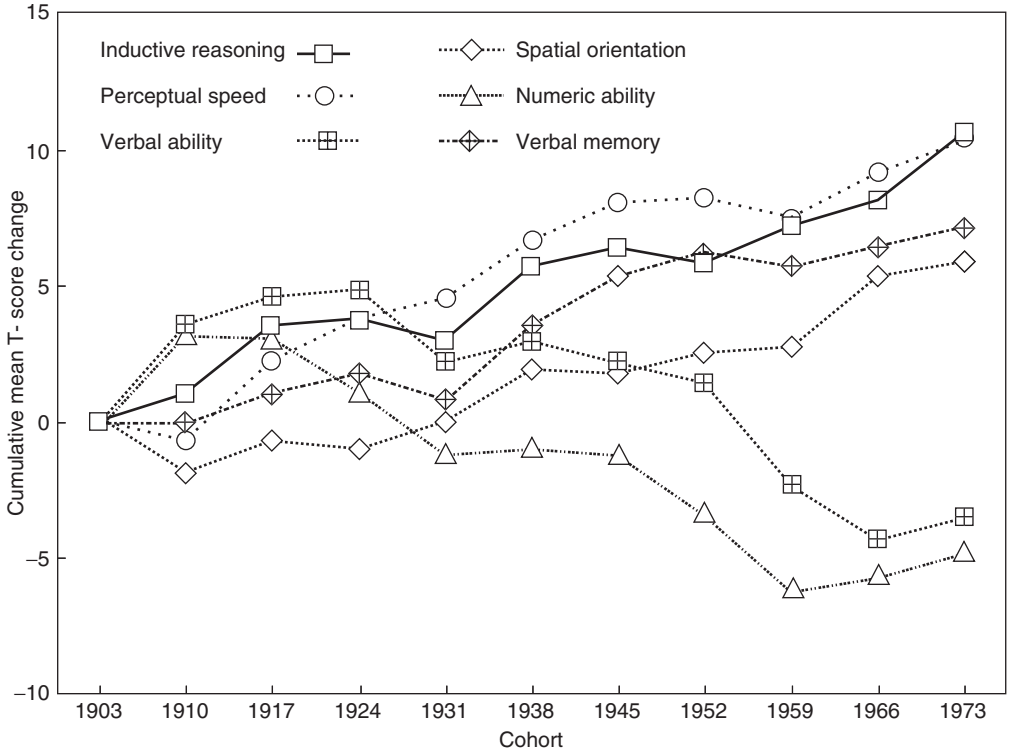

Figure 1 Cumulative generational differences of six mental abilities for birth cohorts in 7-year intervals from 1903 to 1973. From Schaie KW (2005) *Developmental Influences on Adult Cognitive Development: The Seattle Longitudinal Study*. © by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

as a cross-sectional inquiry of Thurstone's primary mental abilities over the age range from the 20 s to the 70 s. Longitudinal follow-ups were conducted at six successive time points (7 years apart) in 1963, 1970, 1977, 1984, 1991, and 1998. All study participants were community-dwelling members of a health maintenance organization and represent the upper 75% of the socioeconomic spectrum. **Figure 1** shows cumulated generational differences for birth cohorts from 1903 to 1973 in 7-year intervals for six primary mental abilities: verbal ability (recognition of the meaning of words); inductive reasoning (the ability to abstract rules and principles from reoccurring single instances); spatial orientation (mental rotation of objects in two-dimensional space); numeric ability (skill in simple mathematical operations such as addition, subtraction, and multiplication); perceptual speed (rapid identification or matching of simple objects, or comparison of numbers); and verbal memory (immediate and delayed word recall). All abilities were measured by three or four different tests.

Substantial positive and linear generational differences were observed for inductive reasoning, perceptual speed, and verbal memory. The 70-year gain amounted to approximately 1 standard deviation (SD). This gain is likely to be associated with the substantial increase in educational exposure occurring over this time period. The positive gain across successive generations in inductive reasoning may also be related to changes in educational practice from rote learning to the encouragement of discovery methods. The virtual conquest of childhood diseases and the adoption of more favorable lifestyles in successive birth cohorts may also be implicated. A similar positive, although less steep, difference pattern occurred for spatial orientation. By contrast, verbal and numeric abilities seem to have peaked in the second decade of the twentieth century and have declined somewhat since then, but was stabilizing in the most recently born cohorts. The same changes in educational practices that have been favorable for inductive reasoning may have led to some loss in number manipulation skills as well. The decline in numeric ability across recent cohorts explains the fact that current cross-sectional studies suggest relatively little decline in numeric ability even though substantial decline has been found in longitudinal data. Generational differences of a magnitude similar to the inductive reasoning factor have also been observed for a measure of practical intelligence involving common everyday tasks.

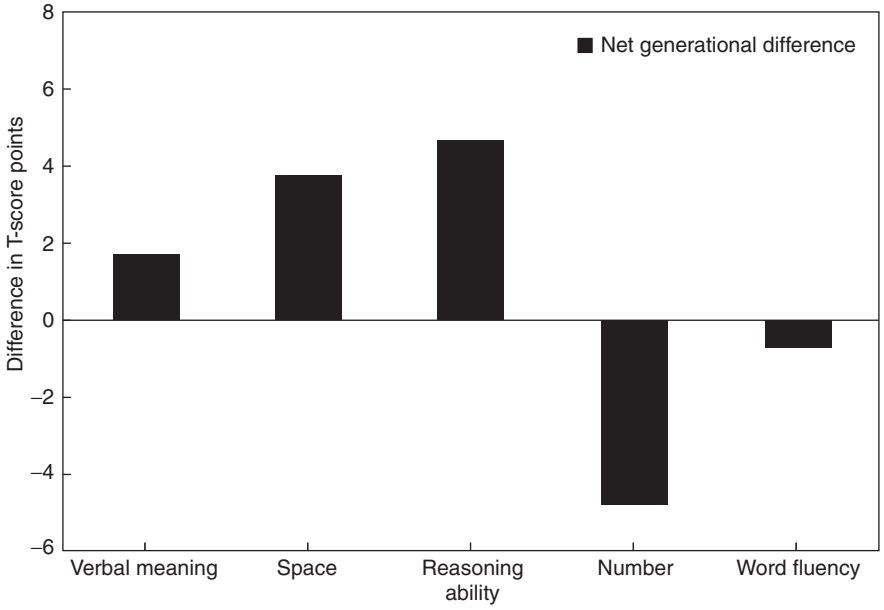

Figure 2 Generational differences in primary mental abilities between parents and their adult offspring. Adapted from Schaie KW (2005) *Developmental Influences on Adult Cognitive Development: The Seattle Longitudinal Study*. © by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

Comparisons from family studies of biologically related individuals involving parents and their adult offspring have yielded similar findings on generational differences in cognitive abilities. **Figure 2** shows findings on tests of five primary mental abilities for the difference between parents and their adult offspring. The bars show the net difference, adjusted for age, in a large data set of more than 600 families. If there were no differences between generations, the solid bar would be zero. As can be seen in the figure, there are significant differences that favor the younger (offspring) generation on inductive reasoning, spatial orientation, and verbal ability. On number ability, it is the older generation that is at an advantage, while there is little difference on word fluency.

These findings are supported in extensive analyses by Flynn, who studied differences across generations of young adults from 1932 to 1978 in the United States as well as in 14 different countries and who also reported massive gains in IQ over the past half century.

In addition to studying level of generational differences in cognition, we have also examined generational differences in rate of change over 7 years in parent–offspring dyads at comparable ages. **Figure 3** shows 7-year changes for six abilities from age 60 to age 67. Again, we see higher levels for the second generation for all variables except number. What is most noteworthy, however, is the fact that while the parent generation showed decline over this age range, the offspring over the same age range show stability or modest increment, except for word fluency and number skills, which continue to show relatively early declines.

Generational Differences in Selective Demographic Characteristics

Gerontologists have long been aware that some of the age difference findings reported in the literature are clouded by the non-comparability between the young and the old of a variety of demographic characteristics. Often these differences have been interpreted as inevitable products of the aging process, and investigators have failed to correct for them. Some studies have shown that a number of these demographic differences actually have little to do with the aging process, but rather must be attributed to generational differences. Examples of substantial generational differences in demographic characteristics include educational level, age at first marriage, and age at birth of first child.

Over the range of birth cohorts represented in the SLS (1889 to 1973) there has been a steady increase in years of education, amounting to a difference in education of about 5.5 years between the earliest and latest cohorts studied. As shown in **Figure 4**, the increase has been close to 1 year greater for men than for women. Age at first marriage, as shown in **Figure 5**, declined by approximately 4 years from the earliest cohort to those born in the 1930s (the lowest level for men was reached by those born in 1938 and

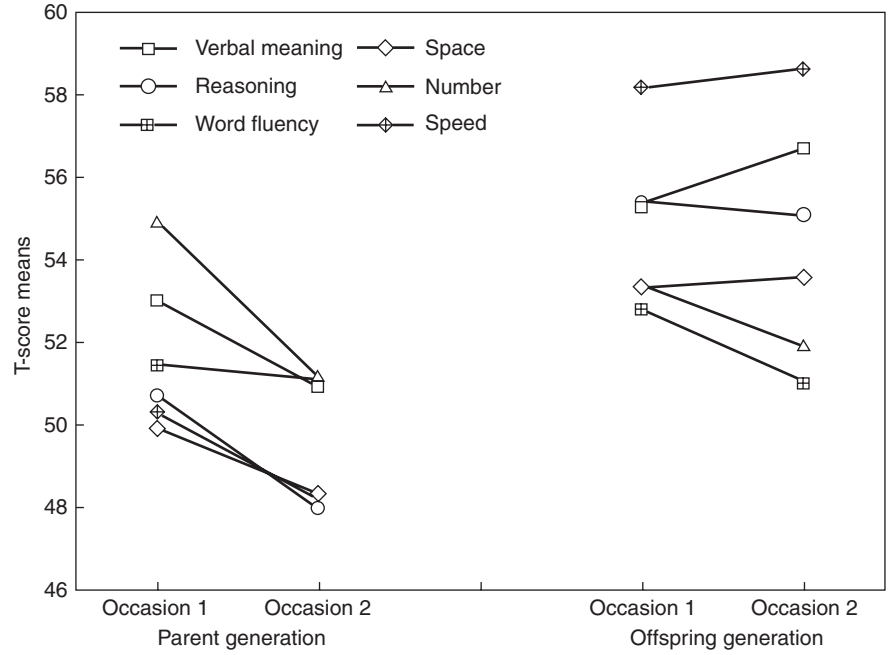

Figure 3 Generational differences in rate of cognitive aging over 7 years from age 60 to age 67. Adapted from Schaie KW (2005) *Developmental Influences on Adult Cognitive Development: The Seattle Longitudinal Study.* © by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

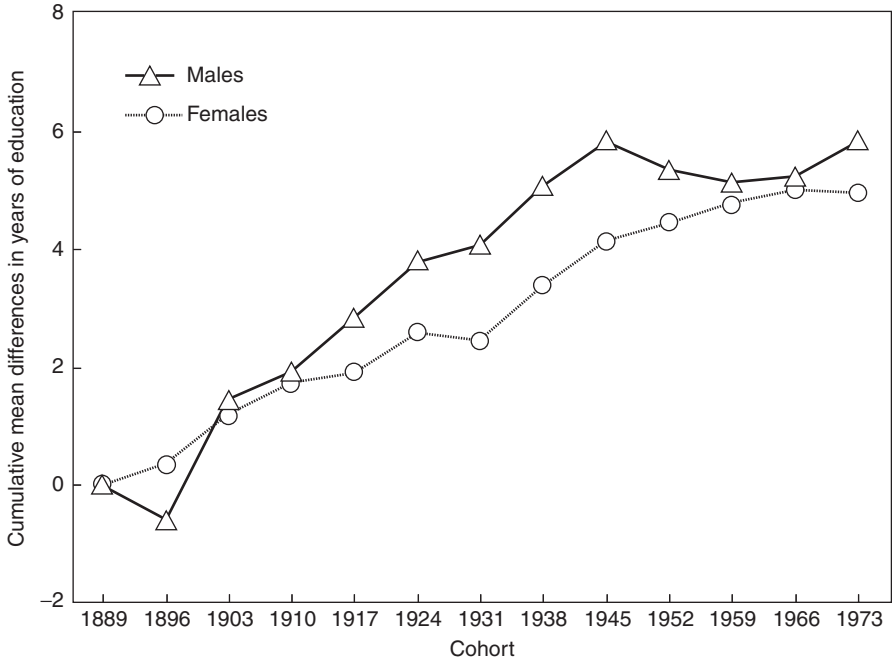

Figure 4 Generational differences in years of education by gender. From Schaie KW (2005) *Developmental Influences on Adult Cognitive Development: The Seattle Longitudinal Study.* © by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

for women by those born in 1931). From then on there has been a steady rise, which is most pronounced for women. As for the age of individuals when their first child was born, for women there has been a steady increment that leveled off at those born in 1959, but it has continued to rise for men. On average, parental age at birth of the first child is approximately 5 years older for the most recently born

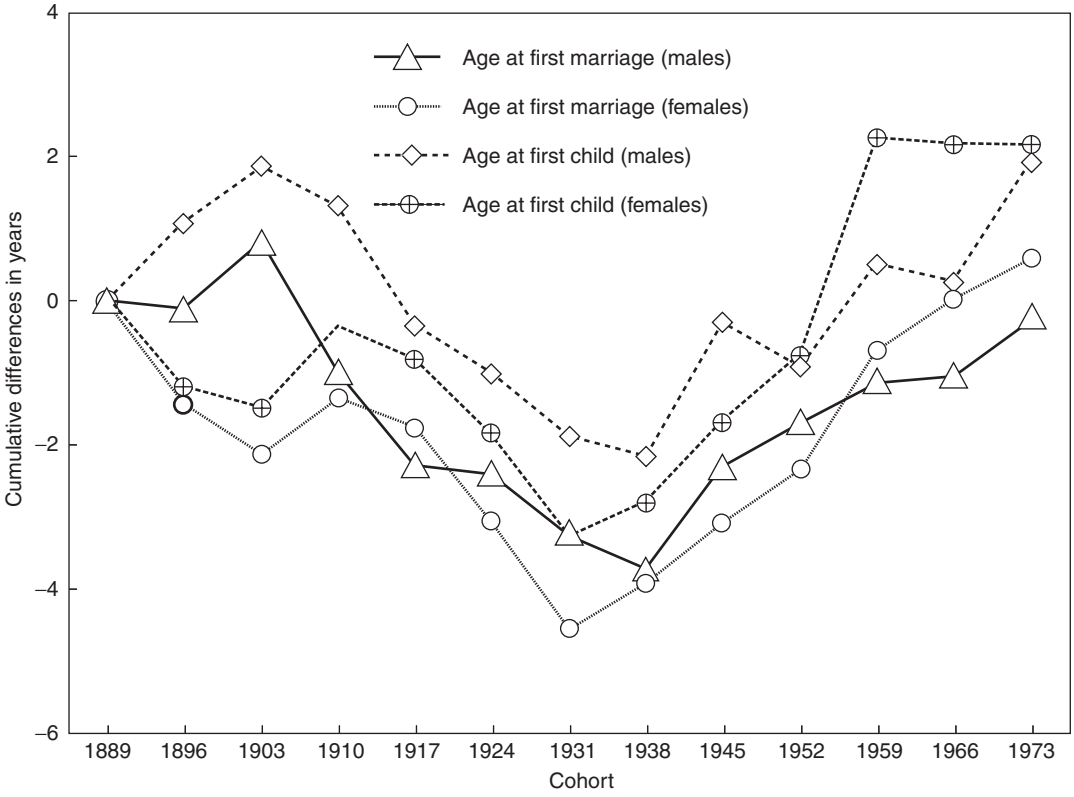

Figure 5 Generational differences in age at first marriage and age at birth of first child, by gender. From Schaie KW (2005) *Developmental Influences on Adult Cognitive Development: The Seattle Longitudinal Study*. © by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

than for the 1930s cohorts. However, recent adult cohorts did not have their first child significantly later than their grandparents.

Other demographic characteristics that may be important in aging studies include measures of mobility (changes in the location of one's home, changes of job, and changes in occupation). **Figure 6** shows average changes for cohorts born from 1889 to 1973 in the 5 years preceding each reporting date. Note that there is a very modest drop in residential and job mobility from the oldest cohort to that born in 1938; over the same cohort range there are virtually no cohort differences in occupational mobility. But mobility characteristics increase sharply for the baby boomer cohorts for all three measures, with residential and job mobility changes showing the most pronounced generational differences.

Generational Differences in Perceptions of Family Environments

A final set of findings of generational differences in geropsychology comes from the assessment of perceptions of family environments by older parents and their adult children within their current families and their families of origins (the families in which they were raised). Although one must always be careful in accepting the veracity of subjective data, particularly when it is retrospective in nature, there is substantial evidence of the utility of perceptions of behavioral dimensions.

In addition to comparing such perceptions across biologically related generations for large populations, it is also instructive to look at shifts in these relationships for successive birth cohorts, similar to those considered previously for cognitive and demographic variables. For example, it may be asked whether there are differences among parent–offspring pairs when offspring are classified into those born prior to World War II, those born during the war years and immediately thereafter, and those who belong to the baby boomers cohorts.

The relevant data inform us that there is a clear differentiation for parents and offspring in the perceived level of all family dimensions between their family of origin and their current families. Obviously the retrospective distance in time is greater for the parents than for the adult offspring. Nevertheless, shifts in the quality of family environments are reported consistently over persons' own life course. The

current families are seen as more cohesive and expressive but also characterized by more conflict than was reported for the families of origin. There seems to be a shift toward greater openness and engagement in family interactions. More intensive family interactions are also reflected by intellectual-cultural and active-recreational orientation from the family of origin to the current family. Along with these shifts there is the

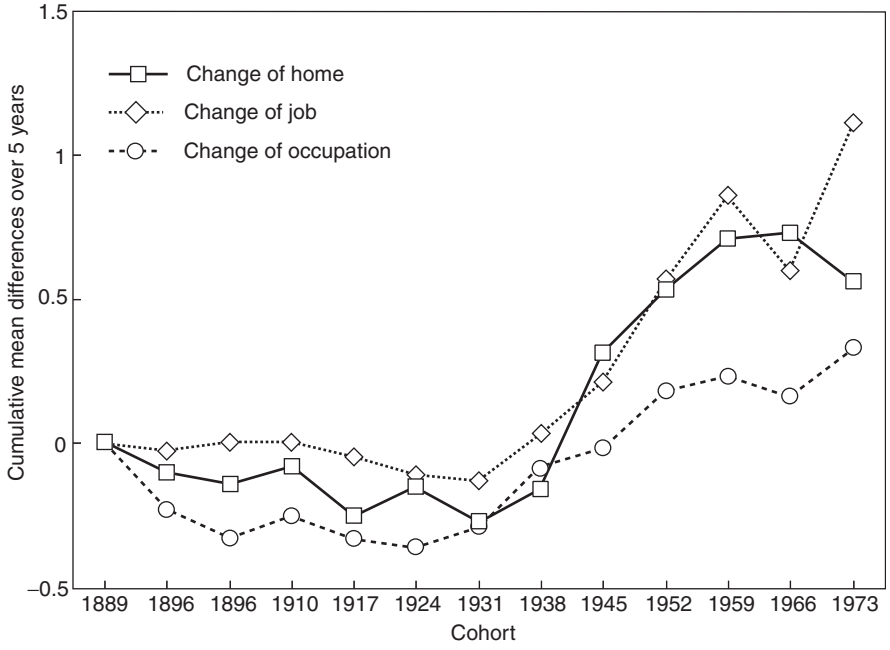

Figure 6 Generational differences in frequency of change of job, occupation, and place of residence. From Schaie KW (2005) *Developmental Influences on Adult Cognitive Development: The Seattle Longitudinal Study.* © by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

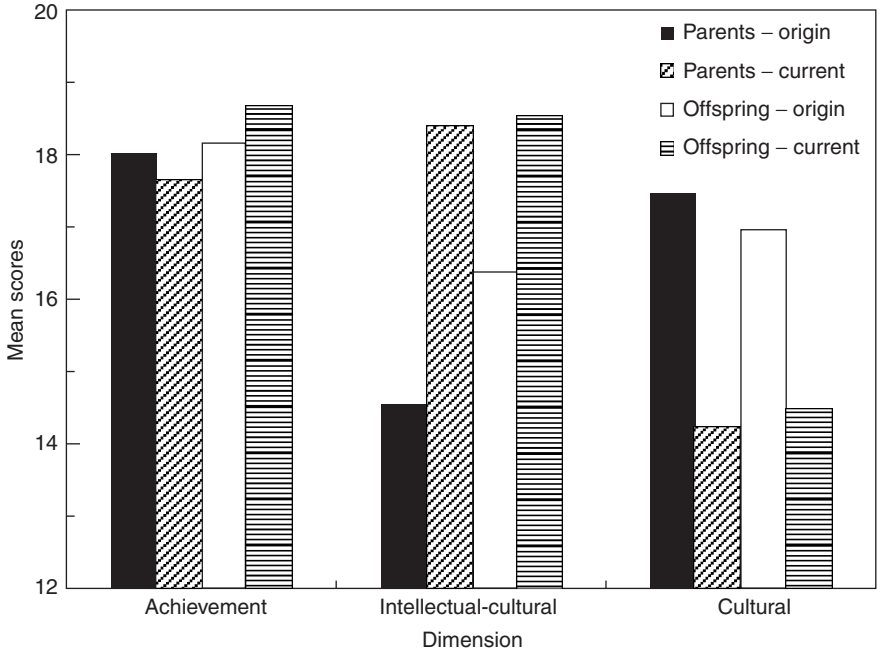

Figure 7 Interaction of perceived family environment by generation and life stage. Reproduced with permission from Schaie KW and Willis SL (1995) Perceived family environments across generations. In: Bengtson VL, Schaie KW, and Burton L (eds.) *Adult Intergenerational Relations: Effects of Societal Change*. New York: Springer Publishing Company, Inc., New York 10036.

overall perception of lower levels of perceived control, family organization, and achievement orientation (see **Figure 7**). Perhaps these judgments are another way of describing the increasing complexity of modern American families. Combined with continuing reports of ever-lower reported levels of social responsibility, this may well mean that the perceived role of the American family is changing from that of a primary socialization agent (operating on behalf of the larger society) to a more effective support system for the needs of the individual family member.

When the two-generation parent–offspring sample is broken down into four distinct cohort groups, it appears that the shifts in perceived family level occurred primarily for perceptions of the family of origin. Perceptions of the current family are much more similar across birth cohorts. This is reasonable, since judgments of the current family reflect the current societal climate common to most, while perceptions of the family of origin reflect different secular periods for which successive cohorts described their early family experiences.

Substantial correlations between parents' description of their current family environment and their offspring's description of their family of origin provide supporting evidence for the continuity of family values and behaviors. Even though there is a substantial time gap in the period rated, these two ratings do refer to the same parental family unit. This similarity of perceptions across generations was particularly strong for three dimensions most closely reflective of value orientations (achievement, intellectual-cultural, and active-recreational) and for family organization.

It is interesting to note that the magnitude of perceived similarity across generations differs by gender pairing and by specific family environment dimensions. It is not surprising that the strongest similarity of family environment perceptions occurs within mother–daughter pairings, even though frequency of contact between adult mothers and daughters is only slightly greater than that for other relationship combinations. In fact, the intensity (frequency) of contact between parents and offspring seems to have virtually no impact upon the similarity of reported family environments.

See also: Longitudinal Studies; Research Design and Methods.

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Genetics

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Glossary

Allele – One of many particular forms of a gene.

Cellular Senescence – The limited proliferative potential of human somatic cells and of cells of many other species that limits the number of replicative divisions that a cell can undergo; also called replicative senescence.

Gene – The basic unit of inheritance; typically refers to the coding sequence and control regions for a single protein or to a DNA region controlling synthesis of a particular gene product.

Genotype – The entire set of genes and alleles of those genes carried by an individual organism.

Gerontogene – A gene involved in aging; usually refers to genes whose normal function involves a shortening of life.

Heritability – Refers to the fraction of the variability in a population that results from genetic effects rather than from environment or chance.

Longevity Assurance Gene – A gene that normally functions to extend life.

Mutant – An organism carrying a mutation, usually one causing an easily observed change in phenotype.

Mutation – An alteration in the DNA leading to a new allele; typically leads to some observable difference in phenotype.

Phenotype – The visible characteristics of an organism, its appearance.

Segmental Progeroid Diseases – Diseases that mimic aging in that they accelerate some, but not all, physiological processes normally associated with aging.

Introduction

Genetics is both a discipline and a research tool. Genetics as a research tool has allowed the identification and reading of the common thread uniting all life on earth, the DNA molecule. Genetics as a discipline has united the biological and biomedical sciences by providing a common framework and tool kit for exploring the multiple processes of life and by providing a common terminology that allows researchers in numerous disparate fields to share information through the identification of genes and the interpretation of their DNA sequence. All of these meanings of the term genetics come into play in this review. Genetics refers to the underlying genetic elements making up living species as well as to the discipline that analyzes these processes. The current state of knowledge of the genetics of aging in humans will first be reviewed. Next studies in model systems that are beginning to reveal the underlying processes associated with aging will be described; much of this work has relied on life span as an end point in the assessment of aging. Finally, we will review the current state of affairs concerning molecular genetic analyses of aging.

Genetics Studies in Humans

Genetic studies of aging in humans have proceeded through several distinct routes. First has been the study of an *in vitro* model of aging: the limited number of cell divisions observed in most, if not all, non-transformed cells in culture, which we will call cellular senescence. Second has been the study of rare diseases that have been termed segmental progeroid diseases to suggest that in each of these diseases many, but not all, aspects of aging have been accelerated. Examples of these include Hutchinson-Gilford disease and Werner's syndrome. Third, both pedigree analysis and population studies have begun; this work may ultimately reveal genes or, at least chromosomal regions, that are associated with various human diseases and with alterations in length of life. Finally, twin studies and other designs have recently been used to begin to determine what proportion of the variation in age-related function or age at death is genetically determined.

Cellular Senescence

Some 35 years ago it was recognized that human cells could not go on dividing forever in tissue culture. This revolutionary observation, cellular senescence, countered classical observation by giants in the field. The acceptance of this fact was quickly followed by the suggestion that the finite proliferative capacity of tissue culture cells might be a model for, or even the basis of, normal human aging. The 1970s saw careful characterization of the aging phenotype of these cells and the finding that the proliferative capacity of these cells declines in parallel with the age of the donor. This fact together with the observations that cell lines derived from certain 'segmental progeroid diseases' have more limited proliferative potential and that proliferative potential correlates with the maximum life span potential of a species, have led many to accept that cellular senescence is a valid model of human aging. More recent evidence seems to suggest that cellular senescence may well be cellular differentiation; many similarities between cellular senescence, as studied in the fibroblast, and muscle cell differentiation can be made. Although the dispute cannot be resolved at this time, it seems likely that cellular senescence is a model for terminal differentiation and has relevance to some *in vivo* cellular aging phenomena.

The analysis of human tissue culture cells is much easier than is the study of intact organisms, and the study of these cells has allowed significant advances in our understanding of cellular processes. The genes responsible for cellular senescence are being identified, and their role in limiting the proliferative capacity of these cells is being elucidated. A surprising result of genetic studies is that in immortalized cell lines, the immortal phenotype is recessive (i.e., a lack

of some essential protein is probably responsible for immortalization rather than the converse). Immortalization seems to result from mutation of any one of four complementation groups; three of these groups have been localized to individual chromosomes. Two recent developments serve to illustrate these points. A gene, variously termed *SDI1*, *WAF1*, or *CIP1*, has been cloned that seems to be one of the players causing cellular senescence. It has been proposed that p21, the protein product of this gene, is involved in regulating the cell cycle by inhibiting cyclin-dependent kinases, thus serving as a checkpoint regulating entry into the S phase of the cell cycle. A second process has also been tentatively identified as a determinant of cellular senescence: the limited proliferative capacity of the telomeres (chromosome ends). Somatic cells lack telomerase – an enzyme that has an RNA cofactor and is used to get around the potentially deadly problem that the 5′ ends of the chromosome cannot be replicated without priming – an absolute requirement of DNA polymerase. The telomere model then states that, in the absence of telomerase, telomeres continue to shorten until chromosome instability and other problems occur. Most, perhaps all, human tumors have reactivated the telomerase allowing indefinite replication. It could be that the absence of telomerase in normal somatic cells is an additional assurance preventing oncogenesis and tumor formation. In any case, these findings have major therapeutic implications and have served as an important focus for current research into cellular senescence (*see* Cellular Aging: Growth Factors and Cellular Senescence).

Segmental Progeroid Mutations

Several human genetic syndromes that accelerate some, but not all, aspects of aging have been described. None of the many syndromes described accelerates all aspects of aging, and thus these are sometimes collectively termed segmental progeroid syndromes. Generally, mutations are deleterious because they eliminate or modify functional DNA sequences leading to an alteration at the protein level; thus, it is expected that mutations should shorten the life span. Hutchinson-Gilford and Werner's syndrome are two diseases commonly called progeria, but Down's syndrome (trisomy 21) accelerates more of the various aspects of normal aging. Werner's syndrome, a recessive, adult-onset progeroid disease has been shown to be associated with extensive genomic deletions of 20 kb and greater. Werner's has been mapped to chromosome 8 and cloning of the gene is imminent. Another progeroid syndrome that has received much attention in the popular press is Hutchinson-Gilford disease, also called progeria because it is manifested as rapid aging in children who carry this autosomal dominant disease. It remains in doubt whether these progeroid diseases reflect the normal aging process or only 'mimic' it.

Markers Associated with Longevity

In an effort to find human gerontogenes, a number of marker association studies have been undertaken. In these studies longevity is shown to be associated with certain alleles and genes within small regions of the human genome by characterizing genetic markers at certain candidate loci. The *HLA* locus has long been a candidate for determining human longevity and at least two studies have suggested that certain *HLA* haplotypes may be associated with increased longevity in at least some populations; the validity of these marker associations at the *HLA* locus remain to be proven. *ACE* and *APOE* have been tested as candidates and both have been found to be associated, although not consistently in the direction predicted. These findings may not be too surprising because of the strong associations between the alleles studied and their effects on health. For example, *APOE-ε4* has recently been associated with frequency of onset and rate of progression of Alzheimer's disease (AD), and certain alleles of the *HLA* locus have long been associated with susceptibility to or more rapid progress of various human diseases (*see* Markers of Aging).

Diseases Associated with Aging

Huntington's Disease A large number of genetic diseases show age-dependent levels of expression and/or penetrance. These include two diseases that are expressed especially late in life: Huntington's disease (HD) and AD. HD is a disease leading to degeneration of the nervous system. The average age of onset is 35–42 years, and the gene segregates as an autosomal dominant. Despite the fact that HD was the first human gene to be mapped using restriction fragment-length polymorphism (RFLP) mapping (chromosome 4), it was only cloned in 1993. That cloning was based on the supposition that the phenomenon of 'anticipation' (seen in HD as an ever-earlier age of onset in succeeding generations) might result from the expansion of a trinucleotide repeat sequence similar to those that have been implicated in a number of other human neurological diseases. An expanded $(CAG)_n$ longer than the normal range was found in all disease families examined suggesting that this was the HD gene. The coding sequence makes a predicted 348-kDa protein of unknown

function that shows no homology to any other cloned gene.

Alzheimer's Disease The best example, and certainly the best studied, age-related genetic disease in humans is AD. About 2–6% of people over 65 show symptoms of AD; the prevalence of this disease increases strikingly with age, such that by 85 as many as 40% of the population may show symptoms of AD. Pedigree analysis has allowed the localization of three distinct genes that are involved in the specification of familial AD (FAD). Rare mutations in the gene encoding the precursor protein of Alzheimer-associated amyloid on chromosome 21 are associated with FAD, but these account for only 2–3% of the affected individuals. Genes on 14 and 19 are susceptibility loci associated with late-onset (after age 65) and early-onset forms of the disease, respectively. There are still other pedigrees in which the susceptibility to FAD is unlinked to these three loci, which suggests that there are still other loci to be found. Thus FAD is clearly very heterogeneous in origin. A further complication is that the degree to which FAD is genetic is uncertain, with estimates ranging from 10–100%. A marked association with the *APOE* locus on chromosome 14 has been shown and replicated in many studies, such that individuals homozygous for *APOE-ε4* have an almost eightfold increase in the probability of getting AD at almost any age when compared with people carrying other alleles of *APOE* (*see* Dementia).

Heritability of Aging and Life Span

From analysis of parent–offspring correlations in life span and differential life spans of identical and fraternal twins, estimates of the fraction of the variation in life span that is under genetic control (the heritability) can be made. Human heritability studies suggest modest amounts of inheritance of longevity, perhaps on the order of 10–30%. Longitudinal studies of various traits suggest that the heritable proportion may change with age in rather surprising ways; unfortunately, little of this material has been published. An other recent area of inquiry is into the genetics of demography. Clearly genetic variation within and between populations plays a major role in affecting demographic predictions of survival.

Model Systems

Genetic studies of aging and age-associated effects can be most effectively carried out in species other than humans. The most popular model systems have been mice; however, the long life span and high expenses of maintaining rodents have led a number of investigators to study invertebrate models including *Drosophila melanogaster* (a fruit fly), *Caenorhabditis elegans* (a nematode), and several fungi including *Neurospora crassa, Podospora anserina*, and *Saccharomyces cerevisiae*. Advantages of invertebrates include lower expenses, a life span of weeks or months (instead of years), and much more powerful methods for genetic analysis, including selective breeding and the identification of mutants that have altered aging processes. Because many genetic alterations can shorten life span, most genetic studies have involved the study of longer-lived strains. Only in invertebrates have mutations that lengthen life span been found.

Early studies largely focused on proving that genes play a role in determining longevity or rate of aging and on quantitative estimates of this genetic component through estimations of heritability. Genetic studies have used one of three different approaches (polygenic analyses, identification of mutants, and construction of transgenics). Each approach is based on a different level of background knowledge, the different fields of training of the investigators, and the desired level of understanding. The most powerful approach for understanding biological processes – the identification of mutants and the subsequent cloning and molecular dissection of the underlying molecular mechanisms responsible for the phenotypic alterations – have only been pursued in a few species, and only in *C. elegans* has the approach really been pursued in any depth. In the last 10 years a number of studies have begun to yield useful information. A molecular understanding of the basis of extended longevity is beginning (*see* Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates).

Polygenic Approaches

Many different alleles for many genes can be found in natural populations. Several approaches have taken advantage of this variation: selective breeding, the analysis of recombinant inbred progeny, and the construction of stocks in which single chromosomes from wild populations have been introgressed into a standard stock. These studies are invariably polygenic in that many genes (sometimes hundreds) can contribute to the differences in phenotype, including differences in life span and other life history traits. Such studies have shown significant genetic components for longevity in mice, in fruit flies, and in the nematode. Typical heritability estimates are in the range of 15–30%. These studies also clearly demonstrate that many genes affect this variation in life span.

Mice Smith and Walford observed that strains congenic for the *H-2* locus (part of the mouse major histocompatibility complex [MHC]) showed significant differences in longevity and that certain *H-2* alleles were associated with increased longevity. These strains were also associated with altered levels of phytohemagglutinin response, DNA repair, free radical scavenging enzymes, and cAMP levels. Affects of the *H-2* locus on age of onset of reproductive cyclicity have also been shown. Frequency of cycle time and age of loss of reproductive potential have also been related to *H-2* genotype. Several other genetic studies have shown that the *H-2* locus or genes near to this locus do have an effect on life span, although the effect of this region may be no more than many other regions of the genome. In crosses between *C57*/DBA F_1 mice and their DBA parents, the largest single-locus effect on average life span was associated with the *B* coat color gene rather than with the *H-2* locus, but if one looked at 90th percentile of survival, the *H-2* locus showed the largest effect. Moreover, there was a small but significant effect of *H-2* heterozygosity, with hybrid strains being slightly longer lived. This study shows that many regions of the genome contain genes with alleles that affect life span and that *H-2* is not unique.

Life spans of 20 BXD (C57BL/6J X DBA/2J) recombinant-inbred strains were determined in an effort to identify the genes (quantitative trait loci [QTLs]) that affect length of life. The mean life spans of most of these strains were very similar with a few extremes (mean life spans of 479 days vs. 904 days). In a simple regression analysis, 43% of the loci had effects on life span. After more appropriate statistical analyses, there were six genetic regions that were significantly associated with length of survival; the *H-2* region on chromosome 17 was not one of them. Again the MHC region was not detected as having major importance in determining length of life.

Lines of mice have been bred for high or low immune responsiveness. These high and low antibody responder lines have mean life spans that are positively correlated with response to antigen ($r = 0.97$). Further quantitative analysis suggested that high responsiveness is almost dominant over low and that the mode of inheritance is polygenic with three to seven independent loci being involved in the response. A major problem with these selective breeding studies is that the low line had a mean life span of only 346 days, significantly less than the typical inbred line. Thus, much of the selective response is in the direction of shorter life span, as expected for mice that have a reduced immune response. Therefore, the alleles selected in this study are likely to be ones specifying lower immunity and consequently a reduced life span. Additional confirmatory selective breeding has recently been undertaken to test these earlier findings, but results of these new studies are not yet available.

Another approach to the genetics of aging has been through the study of senescence-accelerated mice (SAM). These mice were identified as spontaneous isolates in a mouse colony in Kyoto and their exact origin is unknown, but they probably resulted from the mating of two or more distinct strains. These mice have shorter than normal life spans and many aspects of the aging processes have been accelerated. They represent a progeroid model of mouse senescence and are being more widely studied despite the lack of knowledge surrounding their origin. Because certain aspects of senescence seem to be differentially accelerated in one or more SAM strains, they may represent a useful resource, but it remains to be proven that the senescence acceleration reflects normal aging rather than merely mimicing certain aspects of the normal aging processes that have been elicited as a result of one or more mutant alleles in a SAM strain.

Drosophila Despite the failure of selection directly for extended life in fruit flies (*Drosophila melanogaster*), several groups have successfully selected for extended mean and maximum life span by selecting for late age of reproduction. These selections have been performed in outbred populations of fruit flies that had been captured and kept in the laboratory for some time. These selections resulted in an almost twofold increase in longevity and significant increases in late-life reproduction. The increased late fertility was associated with decreased early fertility. Quite surprising is the fact that this increase in life span is not seen in all environments and is dependent on larval density. Under low larval density no differences between selected and control strains were observed. This dependence on growth conditions may explain the earlier negative reports for selection for longer life and also points to the extreme care that must be used in performing selections or other quantitative genetic analyses on life span and probably on other life history traits as well. These environmental effects could also point to important physiological and environmental interactions that could be exploited to determine the molecular basis of this differential longevity.

Longer life is also associated with reduced ovary weight early in life and increased resistance to starvation, desiccation, and other environmental stresses. Indeed, selection for increased desiccation resistance yields longer-lived lines. These responses result from the action of many (even hundreds) of

genes or QTLs. Attempts to dissect the process further have revealed regions of the genome that may be especially rich in QTLs, but further dissection has met with little success, perhaps because so many QTLs are involved. Generally, the results are consistent with a trade-off between early fertility and extended life span as might be predicted by the evolutionary theory of aging. However, these are not critical tests of the theory because so many genes are being selected for simultaneously and thus the trade-off may not be at the level of the individual gene. Moreover, it is bothersome that numerous failures to confirm the theory have been discounted by the proponents of this theory. There has been no clear demonstration in *Drosophila* of the pleiotropic action of a single gene on both life span and some other life history trait, such as development or fertility. Moreover, classical studies by Maynard Smith, although frequently cited as showing such pleiotropy, have not been adequately replicated by modern laboratories studying these processes.

The long-lived strains were also resistant to a variety of environmental stresses including free radicals. Indeed at least two different groups have suggested that the physiological basis of the extended life is increased resistance to reactive oxygen species. A variety of other specific physiological alterations have been implicated in these long-lived strains, but none of these alternative models have been critically tested in these selected lines. At least one attempt to critically test the involvement of superoxide dismutase (SOD) in extended life resulted in a failure to detect a significant effect, but this finding was dismissed post hoc because this locus represented only one of hundreds of genes that were segregating in the population. This apparent lack of ability to refute this model suggests that selective breeding for increased life span in *Drosophila* is not likely to yield additional relevant insights into the molecular and physiological basis of life extension; for that other approaches are needed, as described next.

Nematodes Although several species of nematode have been used to study aging, *Caenorhabditis elegans*, a small, free-living soil nematode that was initially chosen by Sydney Brenner to study development and behavior, has proven to be the nematode of choice for all recent studies because of its excellent genetics. Several thousand genes have now been closed in *C. elegans*, and most of the genome is readily available as an ordered overlapping collection of cosmids and yeast artificial chromosomes (YACs), which greatly facilitates cloning strategies. Procedures for transforming *C. elegans* have been worked out. Hermaphrodites (XX) reproduce by self-fertilization whereas males (XO) occur only rarely but are useful in stock construction. Each hermaphrodite produces about 250 to 300 offspring during her 5-day reproductive period at 20°C. The average life span for an unmated wild-type *C. elegans* hermaphrodite is approximately 3 weeks, which makes this an attractive model system. All somatic tissue in the adult is post-mitotic.

Because *C. elegans* is an inbreeding species, another approach has been used to identify QTLs that specify longer than normal life spans. Several studies have used recombinant inbred strains, which can be generated very easily due to the self-fertilizing mode of reproduction of *C. elegans*, to ask questions about heritability, genetic trade-offs, and number of genes involved in the specification of life span. Reasonable heritability estimates of 15–30% have been reported; estimates suggest that approximately seven QTLs are involved in determining life span. Some trade-offs between early and the late fertility have been identified, but no trade-offs between fertility and life span or rate of development and life span have been found, although more detailed studies are underway.

Two studies have examined crosses between two wild-type strains (N2 and Bergerac) and identified QTLs that are responsible for increased life span. Both studies localized these genes to various chromosomal regions using the Tc1 transposable element to determine map position and strain of origin; polymerase chain reaction (PCR) strategies have been developed that use Tc1 as a molecular marker that can be assayed in individual worms and used to position QTLs. One approach was to examine populations of worms that were segregating these markers and then to see which markers were selectively enriched in older worms, which would indicate that a QTL of interest was nearby. This study found evidence for genes on chromosomes 2, 4, and the X that may be involved in prolonging life and that a number of loci may be selected against in such populations. Nonetheless, this study was not designed in a way that trade-offs between life history traits could be detected. The other study used recombinant-inbred strains and found that QTLs for life span were found on chromosomes 2, 4, and the X and QTLs for fertility on chromosomes 2, 3, and 4. In neither study was there any evidence for the trade-offs between fertility and life span that might be expected from evolutionary theories of aging.

Mutants

Mutational analysis represents the most effective means of identifying genes involved in a biological process. Unfortunately, mutational approaches are

Table 1 Genes shown to be involved in prolongation of life

Gene name	*Species*	*Effect of mutation*
LAG-1	*S. cerevisiae*	Overexpression: increased number cell divisions; other mutations: complex effects
LAG-2	*S. cerevisiae*	Null mutant: decreased number cell divisions; overexpression: increased number cell divisions
SIR-4	*S. cerevisiae*	Semidominant mutation increase of 50% in cell divisions: altered telomere silencing?
age-1, etc.	*N. crassa*	Up to 10 × increase in conidial longevity
i	*P. anserina*	Double mutant *i viv* shows indefinite growth
gr	*P. anserina*	Double mutant *gr viv* shows indefinite growth
viv	*P. anserina*	Double mutant *i viv* or *gr viv* shows indefinite growth
age-1	*C. elegans*	65% increase of mean life span; little effect of fertility; increased resistance to many stresses
spe-26	*C. elegans*	65% increase of mean life span; > 90% reduction in fertility
daf-2	*C. elegans*	Twofold increase of mean life span (shift to 20°C); dauer constitutive (25°C)
daf-12	*C. elegans*	No effect alone; double mutants with *daf-2* increases mean life span fourfold (20°C); dauer constitutive (25°C)
daf-16	*C. elegans*	Blocks action of *daf-2*, *age-1*, and *spe-26*
clk-1	*C. elegans*	Extends timing of development, some neurological events, and life span

difficult to apply to aging because of the difficulty of identifying mutant strains with altered aging processes or longer life span. A list of genes that when mutated affect length of life is given in **Table 1**. In fungi several mutations that affect life span have been identified. A series of mutations affect conidial viability in the fungus *Neurospora crassa* leading to huge extensions of 'shelf-life' in these mutants. Clonal viability is affected by mutations in a series of genes in *Posdospora anserine*, where either *i viv* or *gr viv* double mutants show indefinite ability to grow. Recently, cellular senescence in the yeast *Saccharomyces cerevisiae* has been used as a model for aging, and mutations in two genes that are differentially expressed over the replicative life span (*LAG-1* or *LAG-2*) can prolong the number of cell divisions. Also mutations in four genes have been found to lengthen the replicative life span of yeast; one of these is *SIR-4*, which plays a role in chromosome silencing.

Although a few studies have been carried out in *Drosophila*, all of the interesting work has been performed in the nematode *C. elegans*. The self-fertilizing nature of this species and the lack of inbreeding depression coupled with the existence of the dauer (an alternative larval stage that can remain immature for months and then resume development to a normal adult with a normal life span) make this species especially attractive for such studies. Screens for long-lived mutants were carried out some 15 years ago using a replica-plating strategy. These screens produced several long-lived strains, but only one of them could be studied subsequently; all mutations were in the first gene thus identified, which was named *age-1*.

age-1(*hx546*), the mutant allele most studied, averages a 65% increase in mean life span (25.3 days vs. 15.0 days) and a 110% increase in maximum life span (46.2 days vs. 22.0 days) at 25°C. Long-lived (Age) mutant strains have no change in rate of development, in behavior, or in other life processes and only modest decreases in fertility, if any at all. Some of the most exciting work in *C. elegans* involves the cloning of genes whose protein products are unknown, a process known as 'positional cloning,' and a great deal of effort has so far failed to reveal a clone for *age-1*, largely because of the difficulty associated with the positional cloning of genes affecting length of life.

There are four other published reports of mutations in *C. elegans* that result in longer life. (a) Mutations in *spe-26* dramatically reduce sperm formation and result in life extensions of about 80% for the hermaphrodite and the mated male. (b) *daf-2* mutants cause dauer formation under temperature-sensitive conditions in which dauers are not usually seen and result in a more than twofold extension of mean life span at the permissive temperature; this extension is blocked by the action of *daf-16*. *daf-2* mutations also affect other life history traits marginally in that reproduction can go on at very low levels for weeks. (c) *rad-8* mutant worms exhibit almost 50% longer mean life span than wild type at 16°C and normal oxygen tension. (d) *clk-1* is a mutation that lengthens life 20–50%, depending on the allele, and also affects many other 'timing events' including the length of embryonic and larval development, fertility and the rate of egg production and behavioral timers such as rate of pumping, food ingestion and defecation. Recently published reports suggest that several other dauer-constitutive mutants also affect length of life. *daf-23* doubles the length of the normal adult life span, and *daf-12* mutants interact with *daf-2* to cause an enhancement of the life-prolongation phenotype to an almost fourfold increase in mean life span. The

dominant, dauer-constitutive mutant, *daf-28*, can also prolong life slightly. Other dauer-formation mutants define a signal-transduction pathway in which homologs to mammalian genes involved in signal transduction can be identified, although the roles of the genes defined above remain unclear. *daf-1* codes for a translational product that has homology to a serine-threonine kinase in the *raf* superfamily and which may be a cell-surface receptor. *daf-4* is the nematode homolog of human bone morphogenetic protein (BMP) receptor with the *daf-7* gene encoding BMP. Finally, *daf-12* encodes a transcription factor of the steroid-thyroid hormone receptor superfamily. Note that none of the cloned genes results in life extension.

Our lab has discovered that most, if not all, long-lived mutants of the nematode are more resistant to many environmental stresses. The bases for this statement are twofold. First, four of the long-lived mutants (*age-1*, *daf-2*, *daf-28*, and *spe-26*) are more resistant to two distinct stressors (thermal stress and UV irradiation). Only *age-1* has been shown to be resistant to reactive oxygen species; the *clk-1* mutation has not been tested for any stressors. Second, induction of thermotolerence via non-lethal heat stress results in a longer life span. *age-1* mutants have higher levels of Cu-Zn SOD and catalase at later ages. *age-1* mutants also respond to thermal stress by expressing heat shock protein 16 (*HSP-16*), an α crystalline homolog, at higher levels than does the wild type. Thus, the *age-1* mutation may be uncovering a common genetic pathway that is involved in the mediation of stress response from a variety of environmental stresses.

Transgenics

The ultimate demonstration that a particular process is affected by a particular gene is to show that altering a single gene affects that particular process. The best way to demonstrate this causality is to alter a particular gene and to demonstrate that this affects the phenotype of interest, for instance, life span. Exactly this approach is used in the analysis of transgenic animals (mice, yeast, fruit flies, and nematodes) to demonstrate an effect on aging as a result of alterations in one or a few genes. This approach is just beginning to be applied to a variety of systems to test specific genes for their effects on life span and/or rate of aging.

The best example of the use of transgenics is in *Drosophila*, where transgenic strains that overexpress both Cu-Zn SOD and catalase by 20–50% have been constructed. These transgenic strains had longer life spans and lower rates of mortality than did the wild type. There was also a decrease in the rate of accumulation of oxidized protein and a delay in loss of physical performance. It should be noted that transgenics for both SOD and catalase had life extensions that were much better than the sum of the two single transgenic strains alone. This might be suggested by the involvement of catalase in detoxifying the hydrogen peroxide radical produced by Cu-Zn SOD.

Transgenic strains of *C. elegans* have been produced in an attempt to clone the *age-1* gene by complementation with a normal exogenous gene, but the cloning is still underway. Several transgenic strains of mice have been examined for their effects on aging and life span. Mouse transgenic strains that express the Aβ peptide in neurons show increased neurotoxicity and reduced life spans and probably show an elevation in the level of apoptotic cell death. Mouse strains carrying extra copies of Cu-Zn SOD have shorter life spans and display some of the toxic effects normally associated with Down's syndrome. Other mouse transgenic strains are currently being tested to see what effects loss of different genes might have on life extension and other age-related processes.

Molecular Studies of Genes and Gene Action

DNA Repair and Somatic Mutation

Almost 60 years ago the suggestion was made that mutations in somatic cells could cause aging. The theory has been extensively tested in several invertebrate metazoans and thoroughly disproved in those short-lived insects. It is unclear whether somatic mutation is a general cause of aging or senescence in most mammalian species, although DNA rearrangements have been implicated in many processes during mammalian aging. Three areas of study continue to be actively pursued as possible causes of aging and senescence in mammals: deletion and rearrangements of the mitochondrial DNA, telomere shortening, and somatic mutation as a cause of cancer.

Convincing evidence has been obtained showing that disruption of the mitochondrial genome specifies senescence in a variety of fungal species. In metazoans there is much less direct evidence for a role of these deletions in causing aging and senescence. Mitochondrial DNA deletions have been found in humans, other mammals, and other higher eukaryotes but at low frequencies, prompting proponents of the theory to suggest that the already characterized deletions represent only 'the tip of the iceberg.' The prevalence of several well-characterized

deletions in older people is unclear and is the subject of active investigation by many groups. Deletions of various portions of the mitochondrial genome have been implicated in a variety of human diseases, but there is no direct support for a causal role for mitochondrial deletions in mammalian senescence.

It is clear that chromosomal rearrangements increase dramatically with increasing age, and several human diseases that cause chromosomal instability have some of the attributes that one might expect for an 'accelerated aging' syndrome. For example, Werner's, an adult-onset progeria syndrome, results in a large increase in the frequency of chromosomal aberrations *in vivo*. Cell cultures from Werner's patients have 10- to 500-fold elevations in the rate of new mutations. Much of the age dependence of cancer has been attributed to new mutations and ionizing radiation both *in vitro*, and in studies with Hiroshima survivors it has been shown to cause elevated levels of malignant transformation. There is also an age-related increase in mutation frequency in human lymphocytes. Unfortunately the relationship for other age-related diseases (dementia, arthritis, osteoporosis, etc.) are not so simple, and there is little evidence for the involvement of mutations in these processes.

Telomeres (the ends of chromosomes) have particular problems during DNA replication that led to the hypothesis that telomere loss could cause the finite replicative life span of fibroblast cultures. Telomere loss does appear to be causally linked to cellular senescence in mammals, and telomerase (the enzyme that replicates telomeres) seems to be reactivated in most or all immortal cells. On the other hand, there is no direct support for a causal role for telomere loss in causing aging or senescence in mammals.

Regulation of Gene Action

Altered gene expression has been put forth as a central mechanism for causing aging and senescence for many years. Even evolutionary models for senescence, which are notoriously free of specific mechanistic predictions, suggest that altered regulation of gene expression might be seen in aged animals. Aging is not development, however. Unlike the situation in development where many genes are being up- and down-regulated at a variety of different stages in gene expression, aged organisms express almost the same complement of proteins as do young animals. A variety of attempts to find altered patterns of expression at the protein level have resulted in only few or no detectable alterations. At the RNA level some genes are modulated but few are turned on or off completely. However, again, unlike development, thee seems to be no large-scale alteration in transcription that is coordinately regulated by the synthesis of new batteries of transcriptional regulatory proteins.

Several systems, including senescent tissue culture cells, tissues, or hepatocytes from aged rats, and invertebrate species (fruit flies and nematodes) are deficient in the synthesis of *HSPs* after a variety of inductive events. In rat hepatocytes this defect has been traced to altered heat shock factor that is needed to induce transcription from the *hsp* genes. An exciting hypothesis is that the longer life span of *age-1*, *daf-2*, and perhaps other longevity mutants in *C. elegans* results from an up-regulation of genes that respond to a variety of environmental stresses. There are published reports of increased resistance to both oxidative stress and thermal stress, and unpublished work from our lab shows that all of the mutants so far identified as being gerontogenes may extend life by up-regulating a variety of different pathways, including resistance to UV irradiation.

By far the most complete understanding for the role of gene regulation in specifying aging and senescence comes from studies on tissue culture cells and may not be a model of aging so much as somatic differentiation. Several genes that are necessary for normal cell cycling are not expressed in senescent tissue culture cells. Several of these genes are regulated at the transcriptional level and are not turned on because of a lack of the E2F transcription factor. Senescent cells also differentially express cyclins and cyclin-dependent protein kinases and overexpress several growth inhibitors. The primary regulator of cell senescence still remains to be identified (*see* DNA and Gene Expression).

The Genetic Frontier in Aging Studies

Effective research strategies are underway, which will allow the identification of key genes and regulatory elements causing aging and senescence or limiting the normal life span. Several key systems, but especially senescent fibroblasts and nematodes, have allowed the identification of crucial genes and processes that limit the normal life span. We can look forward to more and more targeted experiments in mice and clinical experiments in humans that will test our understanding while developing pharmacological interventions into one or more aspects of the aging process. Genetic manipulations and technologies will play a crucial role in the coming era.

See also: Cellular Aging: Growth Factors and Cellular Senescence; Dementia; DNA and Gene Expression;

Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates.

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Gerontechnology

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Glossary

Gerontechnology (also called Gerotechnology) – The study of technology and aging.

Technologies – Tools or artifacts which when properly designed and utilized make life easier, enhance efficiencies, extend capacities, and/or that lengthen life.

Introduction

The age distribution of our population is undergoing rapid and dramatic changes as the Baby Boom cohort enters old age. Technological advances are likewise occurring at an accelerating rate. The intersection of these trends provides many opportunities and perils. Careful planning, interdisciplinary research, and product development leading to the appropriate use of technological innovations can help to enhance the quality of life for the aged and reduce the potential costs and burdens associated with population aging.

This article discusses key intersections between technology and aging. It begins with definitions and a brief snapshot of the causes for the current enthusiasm about working with technology and aging. It then discusses selected sociological, psychological, and gerontological theories, which assist in understanding current and potential impacts of technological innovations. Next, it reviews several domains in which technology and aging are currently being studied and producing significant results. These include computers and the Internet, assistive devices, rehabilitative devices, environmental modification such as universal or senior-friendly design, and telemedicine. The article ends with a brief sketch of current and historical leaders in this emerging field.

As humans advance in age, predictable changes occur in their biological, psychological, and social functioning. Sensory, perceptual, and cognitive abilities undergo many predictable changes (not all negative). The same is true for physical ability (including declines in strength, stamina, and balance; particularly in the absence of exercise). In short, with advanced age, humans are in many respects less able to respond effectively to a variety of environmental demands.

Yet, contrary to previous beliefs, many older adults maintain and enhance their various capabilities well

into their very late years, most wish to continue to live full and meaningful lives, and many are becoming empowered to take the appropriate steps necessary to make these goals a reality. This is particularly important because the life expectancy at age 65 is currently nearly 20 additional years. Steps must be taken to assist seniors with maintaining well-being mentally, physically, socially, and spiritually. Technologies can assist with this goal in a wide and expanding variety of ways.

As societies advance through technological innovation, they too undergo sometimes-predictable change. Employment, education, leisure, political, social, and spiritual domains may all change. It is the intersection of these two mega trends – aging population and aging individuals with rapidly advancing technology that most interest those who study technology and aging. The impact of cohort membership on this interaction must also be considered because cohort is often a better predictor than age. With increasingly deliberate actions, technologies are being brought to bear on the needs and interests of an aging population.

The study of technology and aging is referred to as either gerontechnology or gerotechnology, often interchangeably. This article uses the former as the preferred term to connote all work involving technology and aging intersections. At a recent professional meeting, Jim Fozard (a longtime leader in this field) noted that "gerontechnology provides a systematic way to organize and understand research and education related to technology and aging." One major genesis of this study comes from within the field of human factors and ergonomics (itself a multidisciplinary endeavor involving psychologists, engineers, architects, etc.). Core concerns of this field include several micro-level interactions of individual persons (or their component systems – sensory, perceptual, cognitive, or motor) with specific technological interventions and interfaces that are part of the environment (*see* Human Factors Engineering and Ergonomics).

Gerontechnology also considers many macro-level and social considerations and involves a wide variety of disciplines. For example, it considers what sorts of useful information seniors can find on the Internet and to what end, while at the same time it considers such issues as why older men have difficulty with double-clicking the mouse and how more useable pointing devices might be developed.

The key point is that by linking advances from the multidisciplinary study of gerontology with work in fields such as rehabilitation engineering, architectural design, human factors and ergonomics, and the computer and telecommunications fields, there is currently a significant increase in the number and nature of successful interactions of aging humans with technology at the micro, mesa, and macro levels. These interactions have begun to positively influence health, well-being, and life satisfaction, and show great promise for reductions of cost associated with long-term care. A wide variety of useful tools for independent and successful aging is being developed, produced, and marketed for consumers at an accelerating pace as the Baby Boomers age.

Technologies are variously defined as tools or artifacts, which, when properly designed and utilized, make life easier, enhance efficiencies, extend capacities, or even lengthen life. Technologies can be classified in several ways, for example, as high, medium, and low, or as hard vs. soft (as in hardware or software). Technologies of all levels and types may have a positive impact on seniors, but negative impacts are as likely if the technologies are not properly designed. What seems to have emerged in recent years is a clear intentionality to promote the former.

Selecting appropriate technologies of any kind involves important decisions regarding cost, ease of use, dependability, and consequences of product failure, safety, and adaptability to changing user needs. The common failure of technologies to produce improvements in the lives of elders is of great concern to those who study technology and aging. In fact, numerous examples from both the distant and recent past show less than optimal attention to seniors' needs, wants, and capacities. In a 2000 congressional briefing on technology and aging sponsored by the American Psychological Society, Wendy Rogers reported that users of a commonly owned blood sugar testing kit made clinically significant errors more than 60% of the time.

At the micro level, Rogers and associates from the multi-campus CREATE Centers (Center for Research and Education on Aging and Technology Enhancement) have done a careful task analysis of many household technologies frequently used by older adults and repeatedly demonstrated that failure of proper use resulted from poor design, poor instructions, or a combination of both. Research at places such as CREATE, Gerontech–The Israeli Center for Assistive Technology and Aging, and SENTHA at the Technical University of Berlin, to name a few, provide exemplars of best practices for sustaining and accelerating groundbreaking applied research in technology and aging.

At the macro level, Lesnoff-Caravaglia and others have turned their attention to moral and ethical issues, which must receive more attention. We must not lose sight of the big picture. It is important to pose these questions now as a cautionary note

because the remainder of this article primarily focuses on the good that may be derived with the use of technology. Questions arise such as the following: Under what circumstances and for who is the sacrifice of privacy worth the benefits of having one's house wired for automated activity tracking and analysis systems? Why do we continue to settle for perhaps 100 000 deaths per year in the United States alone due to medical mistakes, and why have we not applied the successful safety standards and practices of the aviation industry to the use of technologies in health care? What happens to social institutions such as family, work, and retirement if (when) technological advances allow for average life expectancies of 160? How is our perhaps overdependence on technology making it more difficult to emotionally adjust to aging and to understand the immutable fact of limited mortality?

Fitting Together the Puzzle Pieces

Why, at the beginning of the twenty-first century, is there a dramatic acceleration of interest and innovation in technology and aging? Why are products reaching the market as researchers, practitioners, designers, and marketers display heretofore unseen intentionality in linking human aging to technological devices? The most obvious answer is market forces related to the aging of the Baby Boomers in first-world countries. Seventy million strong in the United States alone, they have commanded our attention throughout their lives, and now is no different. Several other pieces of this puzzle are now falling into place:

- A specific sense of urgency associated with the aging of the Baby Boomers based on the specter of a growing burden to society as they get old. Technology is viewed as a potential cost saver
- Aging and technological advance are no longer viewed as independent, unrelated, or incompatible
- Research findings on aging have evolved and demonstrate that although many human capacities decline with advanced age, others hold up quite well or even increase. Many others are amenable to intervention aimed at restoring function or slowing decline
- Thirty years of research on environments and aging provides a solid understanding of the multifaceted influence of various micro and macro environmental factors on human behavior and is being applied with the notions of sustainability, usability, universal and senior-friendly design, and smart house technologies
- A belief in the power of interdisciplinary approaches has gained favor, making gerontology and gerontechnology more valued. Improved collaboration and communication channels between basic researchers, product development, and marketing enterprises have begun to emerge. Examples include work by university research labs such as CREATE, corporate attention by Microsoft, Intel, and Honeywell, and so on
- There is a new optimism, previously unseen, that technological products can be useful for a broad variety of older adults
- Entrepreneurs and venture capitalists are joining the endeavor. While this began in the late 1990s, the dot-com bust of 1999 had created a temporary delay.

Optimism and a shifting belief system about aging probably have had the greatest impact. We are finally moving away from a blame the victim view that considers technology and aging to be somewhat oxymoronic. 'He is too old to program his own VCR; let his grandson do it' is being replaced with 'By providing basic training and consumer choice of control/display interface, a range of older users can effortlessly modify environmental, entertainment, and food preparation controls from touch screen panels strategically located around the house, and remotely from their personal information managers'.

The Technology and Aging Imperative

Technology has been widely touted as a quick fix for the anticipated escalating costs associated with aging Baby Boomers. The notion is that effectively and efficiently deployed technologies can cut cost and reduce the burden of care. A recent example of this enthusiasm was the December 2005 US White House Conference on Aging. This decennial event, charged with developing recommendations for research and action in the field of aging, has been largely responsible for setting the groundwork for the enactment in 1965 of Medicare, Medicaid, and the Older Americans Act. The centerpiece of the 2005 WHCoA Exhibit Hall was the Imagine Pavilion of the Center for Aging Services Technologies (CAST), which touted the promise of emerging technologies to help rein in out-of-control health-care costs, to assist family caregivers, to promote enhanced or prolonged life satisfaction, and to compensate for what Arthur Flemming referred to as the "vagaries and vicissitudes of aging" at the 1995 White House Conference on Aging. Indeed, technology is the

centerpiece of many key systems change initiatives currently being promoted by the US Administration on Aging. Similar government initiatives and encouragement are evident in Canada, Germany, and elsewhere.

Theoretical Contexts for Technology and Aging

Because modern technology will be increasingly counted on for its beneficial role in the lives of older adults, it is incumbent that great care be taken. The application of human factors and ergonomic principles to the design of various technologies, devices, and environments provides the greatest opportunity for using technologies to promote successful aging. Attention to such design principles can yield improved personal function in several important domains: mental and physical health, communication, mobility, independence, safety, job performance, life enrichment, and leisure.

Some of the current explosion of products is the result of careful study in the lab and of user-centered design. Unfortunately, some is not. Because of this, it seems particularly important to provide appropriate theoretical underpinnings, which can help to ensure that technological innovations intended for older adults are more positive than negative, more useful than harmful. Because the issues and concerns span several disciplines, it is necessary to build upon rich theories from several sources, which consider various aspects ranging from the macro to the micro level. These theories are included here for their significant heuristic value – they can guide careful research, encourage new questions, and perhaps encourage many innovative uses of technologies for and by older adults.

Sociological Theory: Modernization and Aging

Modernization and aging theory, proposed by Cowgill and Holmes in 1972, noted that while technological advances during the industrial era led to an increase in average longevity and in the proportion of the population that was old, it also precipitated a rather significant decrease in the overall social status of older adults. Surplus workers and surplus funds led to a formal retirement system, causing the aged to lose valued social roles and income. Non-workers at a time when this society had a strong work ethic were devalued, whatever their age. Rapid technological innovations coupled with a child-centered educational system made it difficult for older adults to keep pace with new technologies and other secular change. In sum, the theory proposes that complex interactive mechanisms operating on major social institutions stripped elders of status and control, left them behind in deteriorating neighborhoods, with less material resources, obsolete skills and knowledge, and the anomie of a forced retirement from a meaningful job and into an undefined role of retired.

These phenomena can be credited, in part, for the development of ageism, a pervasive stigma associated with old age, which was not evident in less developed eras and still is not in third-world regions of the world. It is also responsible in large part for the creation of the generation gap. Therefore, in many respects, technology was harmful to older adults.

The modernization and aging theory is instructive as we consider the influence of today's information technologies upon older populations. Will information age technology continue to marginalize the aged? Yes, unless we intentionally marshel technologies to do otherwise. Heidrun Mollenkopf of the German Centre for Research on Aging at the University of Heidelberg is one of the leading writers in this area. Doug McConatha's theory of e-quality, which systematically discusses the Internet's modern variants of the industrial age's institutions, shows how technologies can be intentionally used to assist the aged and transform the same institutions that previously had harmed elders. For example, accessible distributed education delivered via the Internet is helping to make our educational system less child/youth-centered and to encourage lifelong learning. An intentionality to use technologies to improve the lives of elders is gaining momentum and is readily apparent in research labs, Wall Street, and Madison Avenue.

Premature dependence upon new technologies is not always successful, however, at least initially. For example, in the United States during the first half of 2006, seniors, caregivers, physicians, pharmacists, and other providers are mightily attempting to understand and implement the prescription drug benefit portion of the 2003 Medicare Prescription Drug, Improvement and Modernization Act. A frequent news image is of seniors, with younger helpers, glaring at computer screens trying to decide which of the scores of drug plans best meet their needs. The general idea of making information available on the Internet is perhaps not the main flaw. After all, seniors are the fastest growing segment on the Internet. A more fundamental problem is the limited human cognitive capacity to comprehend and choose the best plan among multiple providers based on a variety of drugs and cost variables, and in the context of conflicting advice and advertising from various providers and advocates.

Other Theories from Other Sciences

Neither gerontology nor the other scholarly disciplines were immune from a negative view of aging exacerbated by industrialization. Research as recent as the 1980s focused primarily on a litany of age-related decline. Thankfully, and with important ramifications for gerontechnology, these disciplines have more recently developed a more balanced view and shifted focus to promoting healthy, successful aging. Influential books from the two eras symbolize the dramatic shift: Robert N. Butler's pessimistic *Why Survive? Growing Old in America,* penned in 1975, won a Pulitzer Prize; John Rowe and Robert Kahn, with substantial funding from John D. and Katherine T. MacArthur Foundation Genius Award countered with the optimistic *Successful Aging* in 1998.

Now a growing body of research and theory on aging from multiple perspectives (biological, psychological, and social) has shed the pessimistic stance and provides a more balanced view of aging. For example, research in geropsychology discusses hold vs. no-hold capacities in cognitive functioning. Sociological theory is more optimistic (e.g., activity and reinvestment theories have replaced disengagement for all but the very old and infirm), and recent biological research on exercise, nutrition, and telomeres, for example, has demonstrated real or potential means of slowing the aging process and compressing morbidity into the latest years.

As noted by Rowe and Kahn, successful aging depends on a wide variety of biopsychosocial processes, capacities, and opportunities. According to Rowe, optimism is perhaps the most important variable. Paul and the late Margret Baltes and colleagues have described the need for selection, optimization, and compensation (SOC) as individuals adjust to aging and disease. SOC provides a very useful roadmap for applying technology to aging.

Psychological Theory: Field Theory and Information Processing

Field Theory Lewin's field theory, first developed in the 1930s, proposes that in order to predict, explain, and control behavior we must understand the characteristics of the person and the environment in which behavior occurs. Simply stated, behaviors result from transactions between persons and their environments ($B = f(P, E)$). While this may seem intuitive today, it was the antithesis to Freud's popular notion that emphasized internal and unconscious drives as determinants of behavior.

As psychological theory and research developed during the twentieth century, theorists such as Klaus Reigel described the complex, interdependent, and dialectic nature of the influences on human behavior, and this led to an extension of Lewin's model ($B = f(P, E, P \times E)$). This expanded model, like its predecessor, has significant heuristic value for gerontechnology. For example, technology can be added to the model as an intervening variable, it can be viewed as part of the environment, or the model could be used to predict technology's behavior as follows: The behavior of technological innovations in the hands of seniors depends on the complex interactions of those humans within their environments. The next section further develops this theme by introducing Lawton and Nahimow's ecological theory and Fozard's further elaboration.

Information Processing The development of the information-processing model in cognitive psychology during the 1960s through 1980s laid the groundwork for significantly improved understanding of how humans acquire, interpret, and respond to environmental stimuli. It encouraged researchers to conduct a systematic task analysis of the successive processes of sensation, perception, and cognition. (Note that this approach is what made Rogers' work, cited in the introduction, so important and effective.) Coupling parallel work in human factors engineering and ergonomics better allows innovators to match a variety of new technologies to the needs of elders. Knowledge of which human capacities decline, which hold up, and which are amenable to restoration or rehabilitation helps gerontechnologists to assist with the selection, optimization, and compensation that Paul and Margret Baltes proposed as necessary for successful aging.

Gerontological Theory: Lawton and Nahimow's Extension of Field Theory: A Human Factor of Aging

Powell Lawton and Lucille Nahimow's ecological theory of aging extends field theory to gerontology and fills in several important details. Working on the micro-level, it brings us closer to understanding the core of gerontechnology: How can/should we design and provide technologies to enhance the lives of older adults?

The model encourages us to better delineate and consider relevant characteristics of the person and environment to better predict the behavioral/affective outcomes of transactions between the two. Undesirable outcomes (labeled negative affect and maladaptive behavior) occur whenever competence (person) and press (environment) are significantly mismatched. This can occur when either one is significantly greater than the other.

The most desirable outcomes of person–environment transactions are most likely when press and competence are reasonably well matched. If competence is slightly greater than environmental press, the outcome is described as maximum comfort. When press is slightly above competence, the outcome is a zone where maximum performance potential occurs. Setting demands slightly above an individual's capabilities often yields improve competence or performance. The track and field exhortation to set the bar high but not too high clearly applies to older adults in environments and with new technologies.

Adding Technology to the Model Lawton and Nahimow's model was not intended to speak directly to issues of technology and aging; however, the implications of the model to this work should be clear. Technological innovation can help to continually stimulate and enrich the lives of older adults, pushing them to stay active and involved. They can also assist seniors in adjusting to age-related or illness-related declines in capacities. With such declines, demands from the environment must be similarly reduced in order to avoid precipitating negative affect or maladaptive behavior. The careful addition of assistive technology and environmental interventions (AT-EI) to senior environments demonstrates the power of the ecological model in planning for and developing various technological interventions.

As in earlier sections, it is important to caution about overassisting through technology. Lawton and Nahimow's theory predicts what happens when environmental press is too low for the capabilities of the person. That is, technologies that greatly mitigate environmental demand relative to individual capacities can sometimes trigger negative outcomes – laziness, learned helplessness, and/or real and measurable declines in capacities. In the 1970s Bob Kahn coined the term excess disabilities as an environmentally induced condition that is worse than what would have been caused by organic change within the individual. There has been some renewed interest in this concept in the context of technology and aging. Unfortunately, our best intentions for serving a proximal individual exigency may lead to negative distal consequences. Careful task analysis and longitudinal research will assist us in better understanding consequences of the utilization of various technologies.

Take the example of an elder with difficulty rising from his or her favorite easy chair. While rising from the chair and mobility is the crucial behavior, the impact of the chosen means of rising should be considered. If a low-tech, minimalist solution is satisfactory (such as putting a board under the cushion to provide slightly more support, or buying another armchair that is somewhat further off the ground and which has firmer arms, allowing the person to gain leverage with his or her arms); then perhaps a higher tech solution should not be selected. A chair that at the push of a button actuates a lifting device that delivers the individual to a standing position may unwittingly contribute to a further weakening of leg and arm muscles needed to rise from other chairs, to maintain balance when standing, etc. Mollenkopf, Lesnoff-Caravaglia, and others have noted that the long-term outcomes of inappropriate technology adoption may be undesirable.

Adding Secular Change to the Model James Fozard adds an important technology-related dimension to Lawton's model by discussing secular change. After reviewing pertinent research by a variety of investigators he has concluded that all cohorts experience technology somewhat differently, based primarily upon their age when each technology was initially introduced. One's cohort rather than one's age may be a better predictor of affinity toward and ability to utilize specific types of technologies and technology interfaces. Consequently, technology innovators will need to continue to consider alterations to appropriate design, based upon the aging of successive cohorts. In other words, cohort-appropriate design is as important as age-appropriate design (**Figure 1**).

An Example of Secular Change In 2006, the notion that old people can't program their VCRs is still a familiar stereotype about today's older cohort held by individuals of roughly age 30 and up. Yet, as Baby Boomers age, most will maintain their ability to program the VCR and to use other familiar technologies. However, secular change – the evolution of video recording from tape to digital – not only renders the VCR obsolete, but also makes this example nearly meaningless to younger persons.

Fozard and associates have provided another very important addition to our understanding of technology and aging by developing a classification matrix of domains in which technological innovations can affect the aged. In a symposium discussion presented at the 2005 Annual Scientific Meeting of the Gerontological Society of America he noted that "we conceive of gerontechnology as relating to five broad areas of human activity: health and self esteem, housing and daily living, mobility and transport, communication and governance, and work and leisure. In each of the five domains the goals for using technology are: prevention or delay of decline, compensation for age-related loss of function, care support

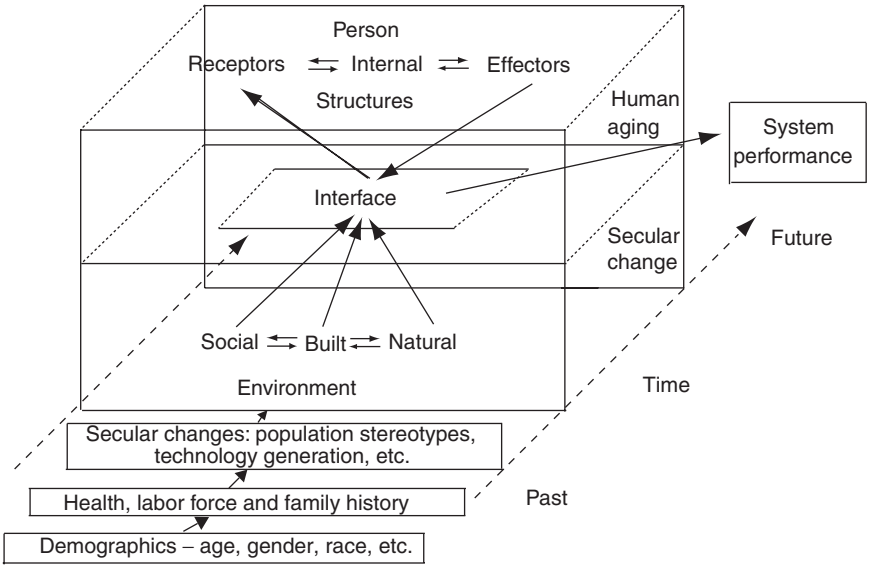

Figure 1 Diagram of dynamics of person–environment interface over time. The interaction of a person and the environment shows the three components of human response to environment that change with age (top half of figure), and the three components of the environment (built, social, physical or natural) that undergo secular change over time (lower half of figure). System performance is indicated by the box to the right of the diagram. Some antecedents contributing to the changing dynamics of the person–environment interface over time are shown in the boxes in the lower part of the figure. Adapted from Burdick D and Kwon S (eds.) (2004) *Gerotechnology: Research and Practice in Technology and Aging*. New York: Springer Publishers.

and organization, and for all of the above, enhancement and satisfaction with respect to quality of life." After briefly reviewing some common age-related changes in capacities, this listing shall serve as our template for considering a variety of uses of technologies for the aged.

Age-Related Changes in Information Processing and Implications for Gerontechnological Interventions

Findings from a growing body of research on age changes in information-processing ability have many implications for technology and aging. These changes are not all negative. With appropriate interventions some age-related declines can be slowed or reversed. The following section seeks to briefly note a few of the more common or problematic changes in sensory, perceptual, and cognitive function and their implications for the design of various technologies (*see* Human Factors Engineering and Ergonomics).

Sensation and Perception

Changes in Vision Several changes in visual sensation and perception occur because of normal aging and/or various age-related disease processes (e.g., cataracts, macular degeneration, diabetic retinopathy, and glaucoma). All have significant implications for environmental design and design of technologies for use by older adults. For example:

- The normal yellowing of the crystalline lens renders colors differently and makes discrimination of short wavelength colors such as violet, blue, and green quite difficult. Video displays, websites, printed advertisements, and so on should avoid requiring discrimination among colors or selection of figure/ground colors in this area of the color spectrum. High color contrast should be maintained.
- The aging lens progressively loses ability to accommodate (change shape) so as to focus in a continuous range from proximal to distal objects. This inevitable presbyopia requires careful prescribing of glasses, contact lenses, and lens implants (in the case of cataract surgery) when sharp acuity is necessary for variable distances. The interaction of age, lens, and distance to and resolution of computer, PDA, or in-vehicle informatics displays must be considered.
- Susceptibility to glare and visual blur increases with age, and visual acuity declines (particularly in the periphery). These changes have several implications for the design of visual displays, signage, etc. Displays with dark background and light text are sometimes preferable.
- Light and dark adaptation takes significantly longer in the advanced years of life. A given scene

or environment appears darker/dimmer for older persons (partly due to smaller pupil openings and partly due to internal neural processing changes). Implications are clear for the need for somewhat brighter ambient and task lighting in restaurants, theaters, etc. Screens on PDAs or cell phones that are carried into environments with dynamic changing ambient lighting should automatically adjust screen brightness to compensate for such changes.

Several researchers have described the implications of the aforementioned changes as well as others (such as attentional deficits) and provide a compelling case for the importance of better understanding the collective impact of these changes upon the functioning of older individuals in dynamic environments. Leading advocates for the application of the preceding knowledge to technologies and environments for the aged include Cynthia Steun and others at Lighthouse International, research sponsored by the SPRY Foundation and conducted by Donald Kline, Chip Scialfa, Frank Scheiber, and others.

Computer hardware (screen size, resolution, brightness, contrast) and software offer many opportunities for users to tailor the screen display to their specific needs and preferences. Successive generations of MS Windows, Office, and other products, as well as the programs of several other vendors, have provided improved user options. Windows, for example, provides a variety of accessibility options and setup wizards for modifying screen characteristics and input device function (keyboard, mouse, etc.) to meet individual needs. Office products include a lengthy tutorial on accessibility features. Unfortunately, work in this area is incomplete, and users sometimes encounter unanticipated barriers when various programs and program settings do not properly work together. Microsoft's Windows vista, due out in 2007, promises to be a significant improvement in usability, particularly for users with impaired vision.

Changes in Audition Changes in auditory function can profoundly effect older adults' interaction with their environments and technological devices. Presbycusis, age-related diminished ability to discriminate high-frequency sounds (e.g., consonants in the spoken language), is the most common age-related hearing loss and makes it difficult for seniors to comprehend speech, particularly when low sound intensities are coupled with noisy environments. Technologies that utilize auditory signals or that transmit spoken information must be cognizant of this fact and be designed accordingly.

A common complaint of young and old alike involves cell phones in which the audible signal of button push success is not loud enough, particularly in noisy environments. Individual needs often conflict with the desire not to disrupt others in the area. More significant a problem is the signal quality provided by cell phones, which is dependent on transmitted signal quality, bandwidth, speaker and microphone design, etc. Another issue is whether cell phones are compatible with hearing aides. The U.S. Federal Communication Commission mandated that wireless phone manufacturers must provide at least two hearing aid-compatible (HAC) digital cell phones by August 2005 and that at least one-half of their phones must be compatible by February 2008.

Changes in Other Senses Age-related changes in gustatory, olfactory, somesthetic (composed of sensitivity to touch, pressure, cold, heat, and pain), vestibular, and kinesthetic senses have all been noted in the literature. As with vision and audition, normal change can be accelerated by, or secondary to, various disease processes. In fact, health status and other variables often exert a greater impact than age alone. Some issues related to technology and environmental designs include the following:

- A combination of weakened musculature and compromised vestibular and kinesthetic sensitivity dramatically increases the likelihood of falls among the very old and/or disabled (*see* Balance, Posture and Gait). Successful environmental design helps to compensate – for example, by minimizing stairs, uneven surfaces, or deep pile/padded carpets and providing handrails and clear visual cues for grade changes and edges. Various technologies have been utilized recently in the assessment and prevention of falls. PERS (personal emergency response systems) such as Lifeline Systems have been developed over the past 20 years that enable users to call for assistance after life-threatening falls have occurred.
- Age-related decrements in sensitivity to heat and cold help to make the aged more susceptible to hypothermia and hyperthermia (heat stroke). Implications for design are clear.

Cognition

Cognition includes processes such as learning, memory, intelligence, attention, creativity, and wisdom (*see* Information Processing/Cognition; Intelligence; Learning; Memory; Memory, Strategies). The inclusion of wisdom in this list is a reminder that

age-related cognitive decline is not universal; for example, the apparent age-related maintenance of crystallized intelligence contrasts to general declines in fluid abilities. Beginning in the 1980s, longitudinal research results have shown that age-related declines occur later and are less severe than what had been documented in cross-sectional studies; many skills hold up quite well in the absence of chronic illness. Significant inter- and intra-individual differences provide implications for design of environments and technological interventions aimed at improving status or function of elders in our society.

Mayhorn *et al*. note that the promise of innovative technology will be unmet unless designers and manufacturers apply user-centered approaches, focusing on needs, capabilities, and limitations of the potential older users. Some important findings and issues include the following:

- Cognitive processes that show age-related decline include working memory and some spatial abilities. Working memory declines are more common as the complexity of the memory task increases and under certain conditions of divided attention. Mayhorn and colleagues provide an interesting example of how this decline can interact with technology in the form of telephone menu systems. The processing demands of a long string of options, coupled with complex semantic meaning, often render these systems ineffective for older adults. The authors recommend careful consideration of delivery speed, ordering from most commonly requested to least, nested/hierarchical menus, etc. Spatial abilities (ability to mentally manipulate objects) undergo consistent age-related change. Such deficits may have an impact upon older adults' ability to efficiently navigate complex websites, utilize informatics displays in automobiles, etc.
- Cognitive processes that hold up or improve with aging include the long-term memory storage of factual information and vocabulary (semantic memory), storage of familiar images (iconic memory), and storage of well-rehearsed procedural memory. Fisk, Mayhorn and others have advocated that the design of technology for older adults should capitalize on these common strengths. This is similar to the strength model of intervention of social work practice – instead of providing interventions that make the care recipient dependent upon a care provider, provide the means by which the individual can utilize his or her capacities in order to stay independent. This relates to Baltes' selection, optimization, and compensation model.
- Some cognitive processes either hold or decline, depending on the specific task. For example time-based prospective memory (remembering to do something in the future) tends to decline, while event-based (remembering a specific event) does not. Time-based tasks can be rendered easier to remember if they are connected to a task (or environmental cue).

Active Domains of Gerontechnology

Previous sections should serve as a roadmap for effective ways to consider and address the intersections of older adults with technology from micro through macro levels. This section briefly provides diverse examples of currently active domains in which technology and aging intersect with increasingly positive outcomes for older adults, their families, others who provide goods and services, and society. These, coupled with examples previously provided, give a good idea of the current state of the field.

Fozard's five areas of influence noted in an earlier section have evolved over several years and are often used in the health promotion literature. They provide the outline here and for each example the primary outcomes of intervention are provided in parentheses.

Health and Self-Esteem

- Health information is increasingly available on the Internet, helping older adults and their caregivers to become informed consumers. The SPRY Foundation (Setting Priorities for Retirement Years) has sponsored several conferences, research projects, and training on improving web design. They also promote health literacy projects so that consumers can assess the quality of online information. (Prevention or delay of decline; compensation for age-related loss of function; care support and organization; and enhancement/satisfaction and quality of life.)
- Several websites of the U.S. Government have become the gold standard for accessibility, comprehensiveness, and usefulness, with information for older adults and their caregivers. Examples include the U.S. Administration on Aging's Eldercare Locator, First Gov for Seniors, information promoting healthy lifestyles, etc. (Prevention or delay of decline; compensation for age-related loss of function; care support and organization; and enhancement/satisfaction and quality of life.)
- The field of telemedicine is expanding rapidly, allowing health-care professional to monitor

patients in their homes on a wide variety of parameters, including body temperature, heart rate and blood pressure, blood oxygen levels, etc.
- A recent technological innovation entitled the Wisdom Circle was profiled on National Public Radio's Morning Edition in February 2006. Two hundred fifty older volunteers from around the United States, including some nursing home residents, provide Internet-based advice, often to younger people. (Enhancement/satisfaction and quality of life.)
- Cognitive well-being can be stimulated by enriched environments. A recent article in *Gerontology Today* describes a growing trend among older Japanese persons to purchase Nintendo Brain Training for Adults games designed to keep mental abilities sharp. More than 3 million units were sold in the first year alone. In the United States, Memory Works, designed and produced by the Practical Memory Institute, is designed to have a similar impact. (Prevention, delay, or restoration of decline; enhancement/satisfaction and quality of life.)

Housing and Daily Living

- Universal design, senior friendly design, smart house with implications for older users have all received significantly increased attention in recent years. Centers leading this work include the Center for Universal Design at North Carolina State University, and SENTHA at the Technical University of Berlin (compensation for age-related loss of function; care support and organization; enhancement/satisfaction and quality of life).
- Technologies designed to help individuals age in place include personal emergency response systems (such as Lifeline), and automated activity track and analysis systems (AATAS) such as Quiet Care (compensation for age-related loss of function; care support and organization; and enhancement/satisfaction and quality of life).
- A wide variety of computer-mediated caregiver support systems have been developed around the country. Some are synchronous, others are asynchronous, and connect caregivers to peers and to professional assistance (care support and organization).
- Anti-wandering devices help to keep patients suffering from senile dementia safe without restraining them or locking down an entire facility (compensation for age-related loss of function; care support and organization; and enhancement/satisfaction and quality of life).
- Assistive technology and environmental interventions include a range of products, services, devices, home modifications, and so on, which for many years have been a mainstay of the fields of rehabilitation and occupational therapy. As these fields turn greater attention to the needs of frail older adults, more positive outcomes are being obtained (compensation for age-related loss of function; care support and organization; and enhancement/satisfaction and quality of life).

Mobility and Transport

- At Johns Hopkins University, George Rebok and associates are bringing together sophisticated simulator technology adapted from NASA and pilot training with neuroimaging technology (fMRIs) in order to develop a better understanding of age-related driver behavior. This work may result in effective means of deciding which older persons should cease or curtail driving. It also can be used to train effective driver skills (prevention or delay of decline; compensation for age-related loss of function).
- At the University of Calgary, Chip Scialfa and associates are working on understanding the characteristics of on-board informatics systems (to assist with way finding, etc.) that are safest and most useful for older drivers (compensation for age-related loss of function).
- The U.S. Department of Transportation has funded diverse research designed to adapt transportation to the needs of a maturing society, including how to make mass transit more user friendly. At the University of Akron, Ronnie and Harvey Sterns are studying ways to improve usability for bus and train timetables (compensation for age-related loss of function and enhancement/satisfaction and quality of life).

Communication and Governance

- Research on the micro environmental level is leading to better understanding of proper design for cell phones and other communication devices. Bill Mann and colleagues at the University of Florida Rehabilitation Engineering Research Center on Technology for Successful Aging have worked with industry to encourage senior-friendly design (compensation for age-related loss of function).
- Modern hearing aides are significantly better than previous generations. Instructions and training help users to adjust and reduce rejection rate (compensation for age-related loss of function and enhancement/satisfaction and quality of life).

Work and Leisure

- At the University of Miami, Sara Czaja and associates are conducting comprehensive studies on tele-work and telecommuting. Based on a growing body of evidence regarding information processing, perceptions and attitudes toward telecommuting, etc., their work is identifying barriers and producing training programs for telecommuting (enhancement/satisfaction and quality of life; prevention or delay of decline; compensation for age-related loss of function).
- There is a wide variety of local and national online learning communities for older adults throughout the world (e.g., Seniornet) (enhancement/satisfaction and quality of life).
- The AARP produces a monthly e-mailed Computers and Technology Newsletter (enhancement/satisfaction and quality of life).

Gerontechnology: Past, Present, and Future

Fozard notes that the early emphasis in the Human Factors and Ergonomics Society (HFES) was on military applications. Gradually in the 1970s and 1980s technical interest groups (TIGs) developed to consider specialized areas of application such as computer operations and vision, or personality and individual difference, rehabilitation, etc. The interest group on aging was slow to develop but now shows robust activity, with a variety of current contributors and contributions.

Other professional/scholarly organizations have sections or groups that focus significant attention to issues of technology and aging. The Gerontological Society of America's Formal Interest Group on Technology and Aging was founded by Gari Lesnoff-Caravaglia in 1987. Today the group has nearly 200 active members and sponsors a listserv and several sessions at GSA's annual meetings. GSA's Formal Interest Group on Physical Environments and Aging (PEA) and on Assisted Living often discusses technological issues. The American Society on Aging's Network on Environments, Services, and Technology (NEST) and Division 20 (Adult Development and Aging) of the American Psychological Association have also demonstrated significant interest in technology issues. (Three prominent gerontechnologists – Neil Charness, Jim Fozard, and Harvey Stearns – have all served as president of APA Division 20.) The Association for Gerontology in Higher Education has recently published a Brief Bibliography on Technology and Aging and a cover story in the AGHExchange on the importance of teaching gerontechnology in diverse courses on aging.

Several other organizations have led the way in the study of technology and aging. The International Society for Gerontechnology was founded in 1997, publishes the journal *Gerontechnology,* and has held four international conferences on gerontechnology. The Center for Aging Services Technology (CAST), founded in 2003, has already become a leading player in the effort to develop and deploy innovative technologies for older adults. It now has over 400 members representing technology companies, government, research universities, and service organizations.

Finally, large corporations such as 3-Com, Cisco Systems, Compaq, Honeywell, Intel, Microsoft, and Sony have gotten involved. Microsoft's Aging and Accessible Technology website provides an excellent summary of the many ways that computers, assistive devices, and environmental modifications are improving the lives of the aged and aging, enhancing the provision of services and health care, and reducing costs associated with population aging. There is, indeed, reason for enthusiasm and optimism in this burgeoning field.

See also: Adaptation; Adult Education; Balance, Posture and Gait; Caregiving and Caring; Creativity; Driving Behavior; Environmental Gerontology; Health Care and Services; Human Factors Engineering and Ergonomics; Information Processing/Cognition; Intelligence; Learning; Leisure; Memory; Memory, Strategies; Narrative and Aging; Perception; Productivity and Age; Psychological Well-Being; Self-Regulation, Health, and Behavior; Social Networks, Support, and Integration; Vision; Volunteer Activity by Older Adults; Work and Employment: Individual.

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Globalization and Aging

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Glossary

Globalization – Refers to those mechanisms, actors, and institutions that link together individuals and groups across different nation-states.

Introduction

Understanding the future of old age requires an appreciation of the possibilities of life in old age across the whole world and not merely those of people living in the West. The topic of globalization is used here to provide a perspective to social gerontology that is often missing from discussions that focus on national health and welfare policies and that fail to locate people within a wider context. Debates on the theme of globalization became highly influential in the social sciences during the 1990s, notably in sociology and in political science. Subsequently, this work was to broaden out with extensive discussions in social policy as well as social gerontology. Globalization has now become an influential force in the construction of old age, most notably in the framing of social and economic policies designed to manage and regulate population aging. Research on aging must be placed within a broader geopolitical framework, with international organizations (such as the World Bank and International Monetary Fund [IMF]) and cross-border migrations creating new conditions and environments for older people.

The main argument developed in this article is that the phenomenon of globalization raises important new

concerns for social gerontology. In general, the focus on globalization confirms the importance of locating individuals within the orbit of social and economic structures, with these increasingly subject to forces acting beyond the boundaries of the nation-state. At the same time, globalization has been linked to the abandonment of those routines and institutions established in what writers such as Giddens and Beck refer to as the first phase of modernity. The sociological argument here is that we are now living in a post-traditional society, in which, in comparison with the past, there is greater emphasis on developing new lifestyles and making fresh choices about the conduct of daily life. This article explores the various dimensions associated with global aging, viewed from within the theoretical framework provided by globalization as an economic, political, and social process. The discussion is divided into five parts: first, an overview of relevant concepts; second, a summary of the dimensions associated with global aging; third, a discussion of global social policy; fourth, a review of the impact of migration and the role of transnational communities; finally, a summary of future trends associated with globalization and their likely impact on older people.

Globalization and Aging

Globalization, it is argued in this article, will have a major influence on the future of growing old. The term globalization refers to those mechanisms, actors, and institutions that link together individuals and groups across different nation-states. Globalization brings forth a new set of actors and institutions influencing the social construction of public policy for old age. To take one example, the increasing power of global finance and private transnational bodies raises significant issues about the nature of citizenship and associated rights to health and social care, in stages of life such as old age. In the period of welfare state reconstruction, rights were defined and negotiated through various manifestations of nation-state-based social policy. Globalization, however, transfers citizenship issues to a transnational stage, driven by a combination of the power of intergovernmental structures, the influence of multinational corporations, and the pressures of population movement and migration.

Following the analysis developed by sociologists such as Bauman and Beck, it might also be argued that rights, in the period of late modernity, have become more fragmented as well as individualized. At one level, the risks associated with aging – the threat of poverty, the need for long-term care, the likelihood of serious illness – are relatively unchanged. What has changed is that the duty and the necessity to cope with these risks are being transferred to individual families (women carers in particular) and individual older people (notably with respect to financing for old age). The new social construction (and contradiction) of aging is, on the one hand, the focus upon growing old as a global problem and issue, but on the other hand, the individualization of the various risks attached to the life course. The tension between these different elements is likely to set the broad parameters around which global aging is developed over the next decade (*see* Critical Gerontology).

Global Aging

The processes identified previously are important in shaping responses to the global trend of population aging. This development is driven by the move from a demographic regime of high fertility and relatively low mortality to one of low fertility and low mortality. The former is associated with fast-growing young populations, the latter with more stable populations, including a larger proportion of people in the older age groups. With the exception of sub-Saharan Africa, no part of the world has been left untouched by this demographic revolution, and the evidence suggests that a return to patterns of high fertility and mortality is unlikely.

The 2002 United Nations report on World Population Prospects suggests that the median age of the world's population increased from 23.6 years in 1950 to 26.4 years in 2000 and will rise to 36.8 by the year 2050. In the 50-year period from 2000 to 2050, the same source anticipates that the proportion of the population who are 60 or over will rise from 10 to 21.4%, but with regional variations within this overall global picture. The pace of demographic aging is increasing fastest in the developing world. It is most noticeable in countries such as China, where fertility is well below replacement levels and life expectancy is greater than 71 years. Projections suggest that by 2025 China alone will contain more people over 60 than the whole of Europe, with the proportion of older people (65 plus) doubling in the space of just 25 years – from 6.96 to 13.2% over the period 2000 to 2005. In Asia, which contains the bulk of the world's population, median age will increase between 2000 and 2050 from 26.1 to 38.7 years. Europe will age at a slower rate but from an older starting point, with the median age over the same period rising from 37.7 to 47.7 years; Oceania and North America will follow a similar pattern.

The situation in the countries comprising sub-Saharan Africa is more complex, given the continuation of high fertility alongside the impact of HIV/AIDS on the region and the high rates of mortality among younger age groups. Nonetheless, two

consequences follow from this: first, with rapid population growth, the absolute numbers of older people will increase, and second, high mortality among younger people is likely to increase the proportion of older people in the population of many African countries. The number of people aged 65 and over is projected to increase by about 10 million in sub-Saharan Africa between 1999 and 2015. While the overall population size will increase by 47% during this period, the growth in the number of people of 65 years or older will rise by 57%.

Population aging will have a major impact on the less economically developed countries of the world. Already, the majority (61% or 355 million) of the world's population of older people live in poorer countries. This proportion will increase to nearly 70% by 2025. For many countries, however, population aging has been accompanied by reductions in per capita income and declining living standards. Fewer than 20% of people aged over 60 in the developing world receive any formal social protection. Between 1950 and the late 1970s, life expectancy increased by at least 10% in every developing country of the world, or on average by about 15 years. However, at the beginning of the twenty-first century, life expectancy remains lower than 60 years in 41 of the 53 countries comprising sub-Saharan Africa.

Older people in the poorest regions of the world are especially vulnerable to disease and illness. The first deaths in famine are invariably found among the very young and the very old. Despite the problems facing older people in developing countries, they may play a crucial role in providing care within the family. This is clearly illustrated in the increasing role of grandparents providing care to children orphaned by HIV/AIDS. Over 60% of orphaned children live in grandparent-headed households in Namibia, South Africa, and Zimbabwe, and over 50% do so in Botswana, Malawi, and Tanzania. According to UNAIDS estimates, about 11 million children have been orphaned by HIV/AIDS in sub-Saharan Africa. Data from 27 countries in the region show that the extended family takes care of nine out of ten of these orphans. In most cases, responsibility for care falls upon grandparents, usually the grandmother. Given that older people are already one of the poorest groups within developing countries, the impact of HIV/AIDS may further exacerbate the problems they face in managing both their own old age and their caregiving role within the family.

Global Social Policy and Aging

Transnational bodies of different kinds are of increasing importance in shaping policy debates in the field of aging. Of particular importance is the way in which globalization as a social and economic process has created restrictions on the development of social welfare, a significant byproduct of the influence of transnational organizations. Financial globalization, to give one illustration, while not a direct cause of the erosion of welfare states, nonetheless sets significant boundaries around their development (*see* Critical Gerontology). A distinctive feature of the present period, as identified by David Held and others, is the extent to which financial globalization has imposed an external financial discipline on governments that have contributed to both the emergence of a more market-friendly state and a shift in the balance of power between financial markets. In this respect, the political agenda of advanced capitalist states increasingly reflects the constraints of global finance, even though the specific impact of financial globalization will vary greatly among nation-states.

A significant aspect of global aging has been the way in which intergovernmental organizations (IGOs) feed into what has been termed, by Carroll Estes and others, the crisis construction and crisis management of policies for older people. A discourse has emerged among leading global actors about the future of social policy, most notably in areas such as pensions and health and social services. Agencies such as the World Bank and IMF have been at the forefront of attempts to foster a political climate conducive to limiting the scope of state welfare, promoting in its place private and voluntary initiatives. The World Bank report *Averting the Old Age Crisis* was a seminal document in promoting the virtues of multipillar pension systems, and in particular the case for a second pillar built around private, non-redistributive, defined pension contribution plans. The World Bank has also argued for reducing state pay-as-you-go (PAYG) schemes to a minimal role for basic pension provision. This position has influenced both national governments and transnational bodies such as the International Labour Organization (ILO), with the latter now conceding to the World Bank's position with their advocacy of a means-tested first pension, the promotion of an extended role for individualized and capitalized private pensions, and the call for Organisation for Economic Co-operation and Development (OECD) member countries to raise the age of retirement (now being put into effect in many European countries). This debate amounts to a significant global discourse about pension provision and retirement ages, but one that has largely excluded perspectives that might suggest an enlarged role for the state, as well as those that might also question the stability and cost-effectiveness of private pension schemes.

IGOs have also begun to exert an influential role in relation to health and social care services. Increasingly, the social infrastructure of welfare states is being targeted as a major area of opportunity for global investors. The World Trade Organization (WTO) has promoted the idea of a more restricted role for the state in the provision of services with an enlarged role for the private (commercial) sector in health services, together with equal treatment for domestic and foreign health providers. The WTO enforces more than 20 separate international agreements, using international trade tribunals that adjudicate disputes. Such agreements include the General Agreement on Trade in Services (GATS), the first multilateral legally enforceable agreement covering banking, insurance, financial services, and related areas. The WTO has called upon member governments to reconsider the breadth and depth of their commitments to health and social services. This will almost certainly place enormous pressure on countries to move further in the opening-up of public services to competition from global (and especially US) corporate providers.

Global Migration and Aging

Migration and the redistribution of people around the world are products of poverty and prosperity but are also profoundly influenced by war and famine and the dispersal of refugee populations. Different kinds of migration can be linked to globalization, each with different consequences for older people. There is internal migration within states that accompanies relocation of populations during the course of development. This typically includes rural–urban migration. Towns and cities expand rapidly, attracting a young population of migrants leaving the rural areas with increasing numbers of elderly people. This was a common pattern in Europe and North America in the twentieth century and is increasingly common in the developing world. There is also the international migration that accompanies development, with people from poorer parts of the world seeking economic opportunities in richer and more developed areas. This not only has the effect of accelerating aging in rural areas, but also has the effect of spreading cultural diversity and the range of ethnic minorities in metropolitan cities. Some migrants settle in their new locations, but some return to their home community, bringing with them new ideas, resources, and possibilities. Many rural areas in Europe and increasingly across the world have come to benefit from the pensions of returned migrants.

The rich members of the world community also move both internally and externally to their nations. They move to find economic opportunity, but there is an increasing movement of people upon reaching retirement, for example, to resort locations both within and outside their own countries. Some of this migration is seasonal, in which extended summer holidays merge with dual homes and retirement relocation. In other cases, the move is either permanent or at least until late old age, when a return journey home may be made. Migration that is related to early retirement is likely to become visible for the first time in the next decade simply because the early retirees will be Baby Boomers from the cohort born in the years following the ending of the Second World War.

A major aspect of migration concerns the development of what has been defined as transnational communities, that is, the social relationships constructed across space that link migrants with nonmigrants. In this context, if what might be called the first phase of aging (which lasted for much of the twentieth century) was about growing old as a reinforcement of national identity and citizenship, the second phase will involve to a much greater extent the development of hybrid identities. Growing old in the first phase – or aging in the twentieth century – was partly a celebration of community, or of lives lived within particular communities with unique histories. In the second phase, however, which we have now entered, belonging and identity may become detached from association with particular places and locations.

Clearly, there will be losers and winners in this process, but the increasing importance of migration and mobility is raising substantial questions for gerontological research in a global context. A world of greater mobility will in the long term bring a number of benefits associated with cultural diversity. But in the short term, an increase in racism and associated forms of oppression also seems evident and may well create further divisions within the population of older people. This appears especially evident in hard-pressed inner city areas, where pressures on resources and services may produce conflict between the majority population and minority ethnic groups.

The rise of transnational communities is likely to bring major issues for social policy, with the development of groups holding together care tasks or financial responsibilities that may be strung across continents. Moreover, the experience of migration – with people in middle and older age settling into new cultures or bearing the strain of moving from one culture to another – raises questions about the adequacy of support in areas such as housing, income, and social services. On the one hand, migrant groups bring new forms of social capital to hard-pressed urban areas; indeed, they may be said to revitalize such communities in significant respects. On the other hand, they may represent a significant challenge for

traditional models of delivering health and social care. A successful response to the latter will require a more sensitive understanding of the distinctive histories of particular ethnic minority groups, as well as improved mechanisms for incorporating their views on ways of improving the delivery of community care services. A critical task over the next decade will be to respond to the diversity of care needs among the multicultural and multi-ethnic populations generated by the social dynamics of globalization. Moving ethnic minority elders from the margins of service provision will be a central part of the challenge.

Studying Global Aging

Taking a global perspective of the lives of older people will be of increasing importance over the course of the twenty-first century. Increasingly, we will appreciate the extent to which older people both live in and are shaped by a world of social and cultural diversity. Reflecting this point, Dannefer has suggested that a new global geography of the life course has begun to emerge, with contrasting experiences in the less-developed as opposed to the more-developed regions of the world. The typical life course pattern associated with Western industrialized countries (the so-called three boxes of education, work, and retirement) is in fact atypical for much of the world. A global perspective on the life course underlines the importance of encompassing a fuller range of human diversity and lifestyles. In particular, we shall need to understand the factors that contribute to the differential shape of the life course, with factors such as transnational flows of capital, the role of multinational organizations, and labor market opportunities being among the key elements.

Studies of global aging will also need to consider the extent to which older people are themselves active within movements that challenge the power of multinational corporations as well as IGOs. Struggles over low pay, decent living standards, and human rights affect all age groups and need to be fully incorporated into pensioners' movements within and across nation-states. Thus far, older people and their representative organizations can claim only limited influence on the major debates about population aging launched by the World Bank and similar organizations. The case that needs to be made is for an age-sensitive globalization in which older people have greater influence in key international fora. Relevant aspects might include the following:

1. auditing the activities of key IGOs in respect of their activities on aging issues
2. building an age dimension into development policies and strategies
3. promoting aging organizations as major players alongside existing multilateral agencies
4. strengthening the age dimension in human rights legislation
5. encouraging older people's organizations to play a prominent role in the network of groups and fora that comprise global civil society.

This is an important agenda, but one that is being only partially addressed in the United Nations, the WHO, and related bodies. This is illustrated by the Madrid International Plan of Action on Ageing (MIPAA), which arose from the Second World Assembly on Ageing. The ultimate goal of MIPAA is to improve the quality of life of older people on the basis of security, dignity, and participation, while at the same time promoting measures to reconcile aging and development and sustaining supportive formal and informal systems of individual well-being. Although such a goal provides a strong platform for developing a new agenda for population aging, the need to engage with growing income inequality must also be confronted. Incomes across the globe became markedly more unequal in the period from the late 1980s to the early 1990s, with research suggesting that the share of world income going to the poorest 10% of the world's population fell by over a quarter; in contrast, the share of the richest 10% rose by 8% over the same period. More generally, research by Wade and others suggests that globalization as it currently operates is increasing inequality within as well as between countries. Such inequalities are creating new forms of exclusion, notably for women, the working class, and minority ethnic groups. Developments such as these require more positive action from bodies such as the United Nations and WHO. The concern of these organizations to encourage the empowerment of older people and to achieve what has been defined as 'active aging' will almost certainly fail unless national and global inequalities – notably those that reduce the life chances of those older people living in less-developed countries and the poorer communities of the developed world – are tackled in a systematic way. Moreover, bodies such as the UN and WHO will need to confront the power of IGOs such as the IMF and the World Bank to impose social policies that result in reductions in expenditure on services for groups such as older people. This has been a particular feature of economic programs directed at Latin American and East European countries and is in direct conflict with the aspirations of the Madrid plan to build a secure and dignified old age across the global community.

In conclusion, globalization – as one constituent of the risk society – may generate new forms of insecurity, of which anxieties and fears about growing old may represent one significant aspect. But other developments may also take place. Will a new cohort of older people (e.g., the post-war Baby Boom generation) give a different voice and meaning to the nature of growing old? If they do, to what extent will this be determined by social networks that embrace global in addition to national contexts? To what extent will globalization undermine the social, economic, and cultural threads (tenuous at best given the role of class, gender, and ethnicity) linking together people identified only through biological age? Globalization has certainly transformed the world, but it is changing the nature of aging as well – and in equally radical ways. Further study of this important phenomenon will be a major task for gerontology in the years ahead.

See also: Caregiving and Caring; Critical Gerontology; International Perspective on Gerontology; Migration.

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Glycation

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Glossary

Advanced Glycation End Products (AGEs) – Permanent, covalently attached glucose-derived modifications on macromolecules.

Deoxyribonucleic Acid (DNA) – Genetic material responsible for transmitting heritable characteristics.

Non-enzymatic Glycation – The spontaneous reaction of glucose with biological macromolecules usually involving sugar attachment to a primary amino group.

Reducing Sugars – Carbohydrates able to reduce oxidizing agents, typically those possessing an α-hydroxyketone, α-hydroxyaldehyde, hemiketal, or hemi-acetal group, and including all monosaccharides.

Transgenic Mice – Mice containing heritable DNA from another source, which is permanently integrated into the genome of each cell.

Introduction

Non-enzymatic glycation is a term used to describe the permanent post-translational modification of protein amino groups by reducing sugars. Although initially applied to proteins in the context of food chemistry, non-enzymatic glycation has been shown to occur slowly under physiologic conditions *in vivo* and is now known also to occur with certain nucleic acids and lipid molecules. The non-enzymatic reaction of reducing sugars to form permanent modifications with proteins not only alters their physical characteristics, but also impairs their biological function. These types of sugar-derived modifications have been termed advanced glycation end products (AGEs). During the past two decades, the presence and biological relevance of AGE modification has been evaluated for a number of important proteins. These investigations have led to an increasing body of evidence supporting the pivotal role of non-enzymatic glycation in the pathogenic mechanisms leading to complications associated with normal aging and diabetes mellitus. This review will focus on the current understanding of the chemical pathway and the biological consequences of AGE modification, and possible methods of pharmacological intervention.

Chemistry

Non-enzymatic glycation was first described in 1912 by the food chemist Louis C. Maillard to account, in part, for the golden brown color of foods following cooking and for the change in taste and texture of foods during long-term storage. The Maillard reaction, or non-enzymatic glycation, begins with the spontaneous formation of a readily reversible Schiff base between the aldehyde group of a reducing sugar, such as glucose, and a primary amino group of a macromolecule, usually a protein. Within a relatively short time (days), the Schiff base can undergo intramolecular rearrangement and reach equilibrium with a more stable, but still slowly reversible, Amadori product (in the case of glucose). Over several weeks, the Amadori product can undergo a series of further spontaneous reactions including inter- and intramolecular rearrangements, dehydrations, and intermolecular condensations to form a heterogeneous array of irreversible end products that are as a group, fluorescent, yellow-brown in color, and stable inter- and intramolecular cross-links. These end products are collectively referred to as advanced glycation end products (AGEs) (**Figure 1**). The formation of AGEs is entirely non-enzymatic and is not known to require any cofactors. The extent of AGE formation and accumulation depends on a number of variables such as temperature, pH, protein and glucose concentrations, and substrate turnover. Although temperature, pH, and protein concentration remain relatively constant *in vivo*, variability in mean blood glucose levels (glucose concentration) and protein half-life (incubation time) significantly influences the extent and accumulation of AGE-modified proteins. Proteins with half-lives greater than a few weeks, for instance, have the opportunity to accumulate more non-enzymatic glycation end products than those that have a half-life of only a few days. Proteins that are continuously exposed to circulating glucose, such as extracellular and serum proteins, also have an increased vulnerability to non-enzymatic glycation. In addition, diabetes mellitus, an illness characterized by chronic hyperglycemia, directly influences the rate of accumulation of AGE-modified proteins in proportion to the degree of mean blood glucose elevation.

The characterization and structural identification of specific AGEs has been impeded by the inherent diversity of products formed during the spontaneous chemical reactions and rearrangements of the non-enzymatic glycation pathway. Using model reactions, a limited number of specific AGE structures have been determined (**Figure 2**). Because glucose is the major extracellular-reducing sugar in the body, it has been used extensively in model mechanistic studies. However, it is important to note that analogous reactions could occur with other reducing sugars. The first AGE to be isolated was 2-(2-furoyl)-4(5)-(2-furanyl)-1H-imidazole (FFI), which was synthesized by incubating glucose with polylysine or bovine serum albumin. Other AGE structures including pentosidine, carboxymethyl-lysine (CML), and pyrraline have also been identified in model incubations, and their presence has been confirmed *in vivo*. Because the process of AGE formation by nature leads to a markedly heterogeneous spectrum of products, the specific yield of any one product is very limited. For this reason, it was postulated that by inhibiting alternate pathways of the non-enzymatic glycation reaction, one could enrich for specific intermediate compounds. Sulfites have been well recognized by food chemists to inhibit non-enzymatic glycation in foodstuffs and have been used extensively in the food industry as preservatives. The presence of sodium sulfite as an inhibitor in a model reaction of glucose and 6-amino-hexanoic acid led to the identification of an AGE intermediate product, 1-alkyl-2-formyl 3,4-diglycosylpyrrole (AFGP).

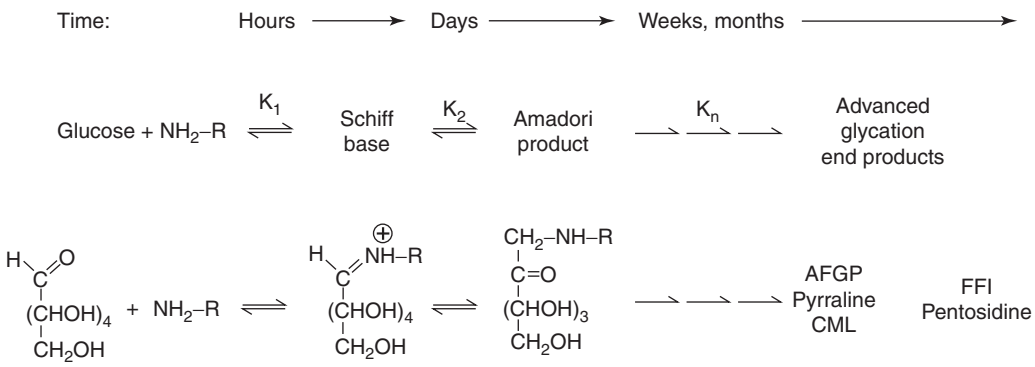

Figure 1 Formation of advanced glycation end products.

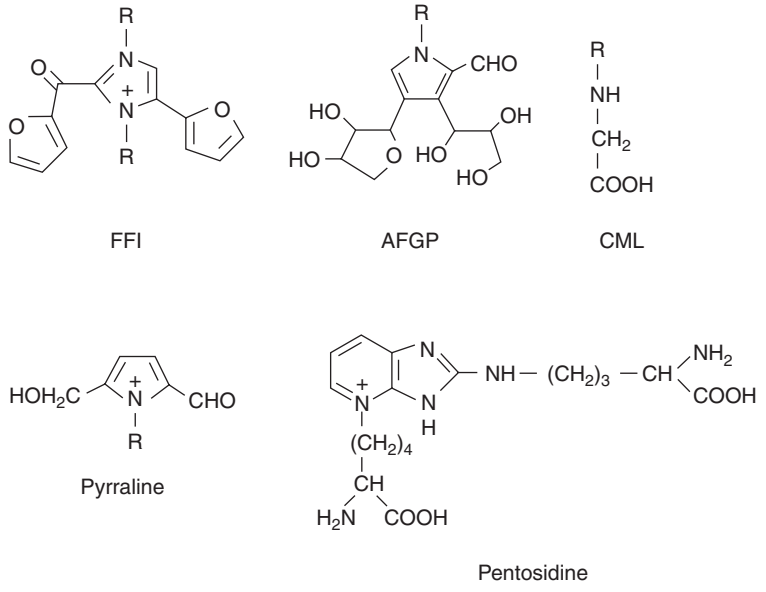

Figure 2 Structures of advanced glycation end products.

Biological Consequences

The formation of AGEs on biological macromolecules alters their structural and functional properties. This type of slow, progressive modification on biologically relevant macromolecules and the accumulation of these modified macromolecules *in vivo* has been implicated in a number of pathologic abnormalities, most prominently the complications associated with normal aging and long-term diabetes. The similarities in the type and development of such complications suggest that the effects of chronic hyperglycemia resemble accelerated aging.

Intracellular Proteins

That non-enzymatic glycation occurred *in vivo* was originally discovered by the presence of a minor hemoglobin species, $A_{1c}(HbA_{1c})$, in erythrocytes. It was later discovered that HbA_{1c} was more prevalent in blood from diabetic individuals compared to nondiabetic. Further biochemical investigations into the origin of HbA_{1c} in blood from diabetic samples demonstrated the presence of a glucose-derived Amadori product covalently linked to the N-terminal valine of the beta-chain of hemoglobin. The clinical measurement of glycosylated hemoglobin in erythrocytes has become an indispensable indicator of circulating mean glucose levels, and is routinely used to assess diabetic control over the 3–4-week period prior to sampling.

Because glucose is found throughout the body, it was hypothesized that other proteins may be sensitive to modification by glucose. Lens proteins were thought to be likely candidates to show the accumulation of AGEs, because these proteins turn over very slowly, if at all. Like hemoglobin in erythrocytes, lens proteins are present in insulin-independent cells; therefore, lens proteins are exposed to glucose levels that directly reflect the extracellular sugar concentrations. In addition, a number of age-related

changes in lens proteins, such as increased aggregation, changes in absorption peaks, and the presence of flurorescent chromophores suggested that non-enzymatic glycation occurred prominently within the lens. In particular, the accumulation of lens protein cross-links contributes to the opacification and cataracts so often observed in aged human lens. *In vitro* studies confirmed that lens proteins could react with glucose or glucose-6-phosphate to result in protein cross-links and lead to changes in absorbance and flurorescence spectra similar to those observed in digests of cataractous lens proteins from aged and diabetic individuals. The observed similarities between lens proteins that were non-enzymatically glycated *in vitro* and lens proteins from aged or diabetic individuals provided the first evidence that non-enzymatic glycation was involved in the development and progression of complications related to normal aging and long-term diabetes.

Extracellular Proteins

The influence of extracellular glucose on the modification of lens proteins provided further impetus to study the significance of non-enzymatic glycation in the pathogenic mechanisms involving other long-lived proteins. Extracellular proteins were considered to be particularly susceptible because, like proteins within insulin-independent cells, non-enzymatic glycation of extracellular proteins would be directly influenced by the concentration of circulating glucose. Collagen is the predominant extracellular protein in the body and the major component of connective tissues, such as skin, tendons, and cartilage. Given its abundance, long half-life, and accessibility by circulating glucose, collagen appeared to have the necessary characteristics for susceptibility to non-enzymatic glycation. Increased collagen stiffness and rigidity is often ascribed to normal symptoms of aging, and this decreased flexibility might be attributed, in part, to AGE-mediated collagen cross-links. The extent of modification of collagen by non-enzymatic glycation has been measured in a number of different collagen-rich tissues including aorta, dura mater, and skin. In each case, the extent to which collagen has become AGE-modified correlates positively with age. Tissue samples from insulin-dependent diabetics show an increase in AGE-modified collagen as a function of chronological age, but the levels observed were comparable to normal individuals twice as old as the diabetic patients. These results reaffirm that the development of some common consequences of normal aging is accelerated in individuals with long-term diabetes.

The presence of AGEs on collagen not only affects its physical and structural characteristics, but AGE modification of collagen can also contribute to atherosclerosis, nephropathy, and peripheral vascular disorders. Studies have shown that AGE-modified collagen can cross-link not only to other collagen molecules, but also to circulating serum proteins. The covalent attachment and immobilization of circulating proteins such as low-density lipoproteins, serum albumin, and immunoglobulins to tissue collagen is thought to contribute to the development of atherosclerotic lesions, thickening of basement membrane in renal tissue, and peripheral vasculature occlusion.

Other Pathologic Consequences

More recent investigations have revealed a potential role of AGE-modified proteins in other age-related pathologies, such as Alzheimer's disease (AD) and brain damage due to stroke. The presence and progressive accumulation of amyloid plaques in brain tissue is a central hallmark of AD, and a great deal of work has centered on the mechanisms leading to the aggregation and deposition of β-amyloid (βA) accumulations in the brain. Recently, amyloid plaques from diseased and normal brain tissues were evaluated for the presence of AGEs. It was found that samples from AD-diseased brains contained almost three times more AGEs per milligram of protein than did age-matched controls. Also, glycation of soluble βA peptides markedly accelerated the formation of insoluble fibrillar βA aggregates in test-tube incubations. These findings suggest that AGEs may be involved in amyloid plaque formation and deposition, and thus contribute to the neuropathologies associated with AD (*see* Dementia).

The exacerbation of another neuropathological disorder by AGEs has recently been observed in a rodent model. Administration of physiological concentrations of AGE-modified proteins to normal rats prior to cerebral artery occlusion caused a significantly larger volume of stroke damage and infarction when compared to non-treated animals. These results suggest that AGEs can initiate potentially neurotoxic processes; however, it is not clear whether AGEs induce damage directly or if they are mediated through one or more secondary pathways.

Nucleic Acids

The identification of non-enzymatic modification by glucose of different classes of biologically relevant macromolecules supports the pervasive nature of this reaction in cells and tissues of the body. A number of years ago it was hypothesized that free amino groups on DNA bases could also participate

in non-enzymatic reactions with glucose, in a manner similar to that of the Maillard reaction with proteins. The non-enzymatic glycation of DNA may contribute to several well-known age-related genetic dysfunctions, such as decreased RNA and protein synthesis, decreased DNA repair and replication, and increased chromosomal aberrations.

Initial *in vitro* studies demonstrated that amino groups of nucleotides, whether free or polymerized in single- or double-stranded DNA, could react with glucose and glucose-6-phosphate. These non-enzymatic reactions generated glycated DNA with altered absorbance and fluorescence spectra, in a time- and sugar-concentration-dependent manner that were directly comparable to the spectral changes observed to accompany the non-enzymatic glycation of proteins. When plasmid DNA, which had been glycated *in vitro* was used to transform bacteria, the glucose-modified DNA had a significantly lower transformation efficiency than control plasmid DNA. This loss in activity correlated with the length of the incubation period and the glucose concentration present in the reaction. Plasmid DNA isolated from some of the transformed colonies was analyzed and found to contain anomalous sequences. These observations supported, for the first time at the molecular level, the hypothesis that non-enzymatic glycation of DNA could have adverse biological effects. Similar results have been observed in other *in vitro* and *in vivo* prokaryotic and eukaryotic model systems, confirming the mutagenic potential of DNA glycation. The effects of DNA glycation can permanently compromise the integrity of the genome and may result in various degrees of impaired cellular function, in extreme cases inducing cell death.

Transgenic mice containing a specific mutagenesis marker gene, *lacI,* were used to determine whether the effects of non-enzymatic glycation extended to the genome in intact animals. By measuring the accumulation of *lacI* mutants as a function of age, it was determined that mutant frequency increased linearly with time. The types of DNA mutations observed were not limited to simple base substitutions, but included large deletions and insertions, suggesting the activity of complex AGE-dependent DNA repair pathways. Given these results over the short life spans of experimental animals, one can also expect that AGE-induced DNA damage and mutations may account for some of the genetic alterations that are observed in elderly humans.

It has been well documented that there is a significantly higher incidence of birth defects in infants born to insulin-dependent diabetic mothers than in those born to their non-diabetic counterparts. Using the same *lacI* transgenic mice, the mutagenic effects of maternal hyperglycemia on developing embryos could be assessed. In fetuses that developed in diabetic dams versus those developing under normal conditions, there was a twofold increase in *lacI* mutant frequency. Molecular analysis of these *lacI* mutants showed a pattern of DNA mutations similar to those observed in aged mice. These similarities suggest a common mechanism of DNA damage and subsequent inefficient repair in normal aging and diabetic pregnancies. This study provided the first potential molecular link between maternal hyperglycemia, DNA damage, and congenital malformations.

Pharmacological Intervention

Specific knowledge of the chemical pathways involved in AGE formation has allowed potential pharmacological inhibitors to be synthesized. The first compound to show promise in this regard has been the small molecule, aminoguanidine. Aminoguanidine can react with a post-Amadori product to form products that do not go on to form AGEs, and is effective in this regard in test tube reactions and in animals. Although still early in the process of clinical assessment, there is encouraging evidence from animal studies that this drug has the therapeutic potential to prevent the development of AGE-related pathologies. It is hoped that better understandings of the chemistry leading to the formation of AGEs will lead to the development of additional anti-AGE approaches with therapeutic potential.

Conclusions

The non-enzymatic reactions initiated by the chemical condensations of reducing sugars with proteins and nucleic acids lead to the formation of irreversible structural modifications, AGEs, which have important biological implications. A number of complications associated with diabetes mellitus and chronic hyperglycemia (e.g., cataracts, collagen stiffening, and atherosclerosis) resemble those characteristics of normal aging, suggesting that the diabetic environment represents a model for accelerated aging. AGEs accumulate slowly in normal aging and more rapidly in the diabetic environment. These molecular modifications appear to account significantly for these similar parthological courses. Therefore, mechanisms that prevent, reduce, or relieve AGE-related diabetic complications can also be expected to improve age-related symptoms. Not only will therapeutic methods of intervention increase the quality of life of millions

of individuals affected by diabetes, but they may also benefit the lives of all older individuals.

See also: Dementia.

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Grandparenthood

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Glossary

Affect – The feelings, moods, and tones expressed in the family.

Extended Family – A group of individuals consisting of the nuclear family, as well as individuals related by ties of consanguinity. Extension of ties exists among parents and their children, grandchildren, and between siblings.

Family – A basic unit of society, characterized as one whose members are economically and emotionally dependent on one another and are responsible for each other's development, stability, and protection. The family serves as the basic unit of socialization to teach cultural values and adaptation to society. Currently, in our society, the traditional definition of the family is undergoing transition because of the emerging prominence of alternative lifestyles.

Generation – A group of individuals constituting a single step in the line of descent from an ancestor.

Instrumental Activity – Behavior that is directed toward a goal.

Intergenerational – Pertaining to or involving individuals in different generations.

Nuclear Family – A family consisting of a husband, a wife, and their immediate children.

Role – A set of behaviors expected on the basis of a particular status. Roles may be ascribed (assigned on the basis of factors over which the individual has no control) or achieved (earned on the basis of individual effort).

Introduction

Grandparenthood is the family role assigned to an individual whose child produces a child. Grandparenthood is also a dyadic relationship involving a grandparent and a grandchild. Grandparenthood has existed for as long as families have included three or more generations. Its associated rights, responsibilities, behaviors, meanings, and satisfactions have varied with factors that are cultural, demographic, social, economic, psychological, and historical in nature. Grandparenthood has been investigated as a role, status, and relationship. Findings have implications for research and practice.

Background

Anthropological Context

Although grandparents have played a role in family life for as long as families have included three or more generations, the nature of this role has varied with a multiplicity of cultural, demographic, social, economic, psychological, and historical factors.

Levels of formality and respect in grandparenthood relationships are directly related to elder power over societal and family structure. In cultures and historical periods where decision making and economic power reside with the old, relations between grandparents and members of other generations are formal and authoritarian, characterized by prerogative and protective care on one side, and by dependence and respect, on the other. Conversely, in cultures and periods in which the old are removed from functional authority, grandparent–grandchild relationships are warmer and more indulgent; they are characterized by a friendly equality that can function to relieve tensions between family generations.

Changing Demography of Intergenerational Relations

Over the course of the twentieth century, changes in mortality and fertility have led to greater life expectancy and to changing rhythms in the family cycle – both of which have dramatically influenced the nature of intergenerational family relations. Reductions in mortality rates, public health advances, and control over once-fatal childhood diseases have combined to increase life expectancies, over the course of that century, from roughly 46 to nearly 80 years. For the first time in history, human beings can expect to live between one-third and one-half of their lives after they have reproduced. Never before have so many individuals lived long enough (and had their children live long enough) to become grandparents. Demographers report that in 1990, 94% of all older adults with children were grandparents, and nearly 50% were great-grandparents. Reciprocally, birth cohorts of children have never before had so many grandparents and great-grandparents.

Extended life expectancies have increased the number of multigenerational families, and have led to an unprecedented emergence of the long-term intergenerational relationships referred to by one family sociologist as 'crescive bonds.' Parent–child bonds may be expected to endure for six or more decades, four of which involve parents and their adult children. Americans today typically become grandparents in midlife; they can expect to spend four or more decades – roughly one half of their lives – in this role. One family historian notes that only since the twentieth century have grandparents and grandchildren enjoyed a meaningful period of overlap in their lives. Contrary to popular misconception, grandparenting has been a phenomenon of middle age for at least the past century. What makes contemporary grandparenthood demographically unique is its duration through both middle and later life.

Twentieth-century America has seen an overall reduction in the number of children per family, and a corresponding contraction in any given family's period of childbearing. These changes have led to an increasing distinction between parenthood and grandparenthood, both as individual life experiences, and as statuses within the family. No longer is it common, in mainstream society, for new grandparents to be actively involved in bearing and rearing their own children. Sociologists point out that when a person becomes a grandparent today, he or she is likely to have fewer family roles competing for personal time and attention than would have been the case in previous generations. Today's competing roles are more likely to be located in the workplace and the community than inside the family. (Increasing life expectancies for the frail elderly may come to replace child care with elder care as a major family responsibility of the middle aged and the young old.)

Socioeconomic Changes

Family historians describe a shift in the family, dating back to the late 1800s, from a corporate unit whose members were bound by lifelong interdependence, to a largely emotional entity whose members stress individual and nuclear independence. This shift in family structure is closely related to society-wide changes in work schedules, retirement, social programs, overall standards of living, transportation, and communication. At the beginning of this period, low wages, unemployment crises, illness, death, and the absence of social welfare programs forced family members to rely on one another for support. Family ties were seen as permanent obligations that took precedence over often transient feelings of affection or its opposite. Over the course of the twentieth century wages and general standards of living have risen, the work week has stabilized at roughly 40 hours, and, in many sectors of society, unemployment crises have diminished. Today's average male can expect to spend 15 years of his adult life retired from the labor force. Control over illness and death have increased. Social welfare and insurance programs have transferred basic financial reponsibility for the elderly, the disabled, and the infirm from kin to society as a whole. Improved transportation and communication technologies facilitate frequent contact across great distances (*see* Economics: Society).

All together, these changes have both permitted and promoted the independence of family generations, nuclear units, and individual members. Obligatory family ties based on need have been replaced with more voluntary bonds based on sentiment and attachment. The family as an institution

governed by strict social mores and laws has given way to what has been described as a 'companionship,' with behavior determined by mutual affection and by membership consensus.

Thus, today's grandparents are likely to have more time and money to spend on their grandchildren than their predecessors did. They are less likely to be raising their own children while actively grandparenting. They are less likely to provide instrumental family services out of need and obligation, and more likely to do so on the basis of desire and affection. Pressures related to work, marriage, education, climate, and security all contribute to the fact that today's grandparents and their grandchildren live at considerable geographic distances from one another. Nonetheless, they are likely to maintain regular telephone contact, and to visit several times a year.

Grandparenthood Research

As discussed above, socioeconomic and demographic trends in the first half of the twentieth century permitted nuclear families to enact the self-reliance and individual independence that constitute this country's most basic social values. It should therefore not be surprising that family researchers in these years all but ignored the grandparent role, which they saw as either ignominiously dependent or anachronistically controlling. Instead, they drew invidious comparisons between the contemporary American nuclear family, rooted in individualism and democracy, and the historical American family, characterized as multigenerational and patriarchal. During this period grandparents appear in social science research, if at all, almost entirely in the work of anthropologists.

By the late 1950s, family theorists began to challenge their earlier neglect of extended family networks. Over the next 15 years scholars began to cite evidence for the modern modality of the American 'modified extended family,' a system of nuclear families bound together by affectional ties, patterns of social activity, and mutual assistance. In addition, family historians of this new period reinterpreted historical data to conclude that harmonious, multigenerational family life had never been common in America. Rather, they asserted, intrafamily cooperation and assistance had always been American norms; along with parents and children, grandparents had always participated in mutual-help networks of kin.

Grandparenthood research in the 1960s and 1970s focused primarily on such singular qualities as love, authority, esteem, and responsibility. Gradually these unidimensional descriptions gave way to more comprehensive typologies. More recent research has attempted to establish causal links between typological categories and a host of demographic, personality, and family variables.

Grandparenthood to Grandparents

Discussions of the grandparent role often confound the components of behavior, meaning, and satisfaction. Perhaps because all three components are difficult to measure, researchers refer to the grandparent role without systematically differentiating among components or investigating their interrelationships. However, although behavior, meaning, and satisfaction are clearly related, they are, just as clearly, conceptually distinct. In addition to these three components, the grandparent role also involves such elements as role ambiguity, career development, timing, and instrumentality.

Behavior

On the basis of interviews with 70 grandparent couples, one study identified five distinct styles of grand-parenting: formal, fun seeker, surrogate parent, reservoir of family wisdom, and distant figure. In a more recent study, 510 grandparents were interviewed to describe three grandparenting styles: remote, companionate, and involved.

Research indicates that most contemporary American grandparent relationships may be described as companionate in style. Leisure and pleasure, rather than labor and responsibility, govern these relationships. Grandparents share fun and games with their grandchildren, enjoying affectionate, informal time together. With respect to matters of discipline, values, and socialization, companionate grandparents say that they hold their tongues and adhere to a widely accepted norm of non-interference across nuclear family boundaries. Some companionate grandparents express regret at having to withhold what they regard as valuable advice, and others want more interaction with the grandchildren, but know they are powerless to get it. Nonetheless, most reconcile themselves to being both connected to and separate from their grandchildren, and they agree that their lack of authority makes grandparenthood relationships uniquely pleasant and comfortable.

The norm of grandparental non-interference is part of what psychiatrist A. Kornhaber disparages as the new social contract, according to which the value of mutual independence supersedes other long-term concerns and short-term needs. Kornhaber reports that after years of heavy family responsibilities, grandparents welcome the opportunity to place their own, individual wishes first. Psychologist

D. Gutmann suggests that more than actually wanting to enact freedom, grandparents want to be seen as embodying societal values of self-sufficiency and independence. Anthropologist C. Johnson maintains that grandparents acquiesce to non-involvement largely because they believe they should not interfere in their children's families. According to this view, grandparents actively pursue interests outside the family essentially to distract themselves from intruding.

Remote grandparenthood relationships are characterized by emotional distance and formal, reserved interactions, as experienced by both grandparent and grandchild. This is the behavioral style most often chosen by today's grandparents to describe their own grandparents, two generations ago. Involved grandparenting entails spending a good deal of time working and playing together. These relationships are both companionable and instrumental. Their ties are based on exchange, on direct action, and on behaviors, concerns, and responsibilities that many companionate grandparents would regard as off limits.

Most grandparents and grandchildren can establish only symbolic bonds unless they see each other regularly. However, although amount of contact is often used in research to operationalize importance of the grandparenthood role, this variable is a prerequisite, not a proxy, for the phenomenon researchers seek to measure. Amount and quality of contact may be influenced by geographical proximity and by grandparent health and competing commitments; research suggests that proximity is the most powerful influence. Serving as 'lineage bridges,' parents can promote or inhibit relationships between the generations on either side. Parents model relationships with older family members, and they provide children with examples of how to relate to grandparents. Parental attitudes toward older people, in general, and their relations with their own parents, in particular, affect the grandparenthood relationships in their own family. Parents serve as gatekeepers to their children. However, despite this acknowledged power in the middle generation, it seems that only rarely do parents deliberately limit grandparenthood contact.

The grandparent role is enacted by means of specific behaviors that are associated with a multiplicity of variables. Age, gender, and marital status influence grandparent behaviors. Older grandparents tend to be more formal, younger grandparents to be more relaxed and playful. In accord with women's 'kinkeeper' role in families, maternal grandmothers tend to be visited more frequently and to be seen as emotionally closer than paternal grandparents. Grandfathers tend to be oriented outside the family, as 'ambassadors,' whereas grandmothers are oriented inward, as 'ministers of the interior.' Widows are more likely to be actively involved with their grandchildren than are remarried older men.

As described in research throughout the social sciences, grandparenthood role enactment is also influenced by variables that may be categorized in terms of family structure (e.g., number of grandchildren; importance of family), socioeconomics (e.g., employment status; educational level; economic resources), social resources (e.g., ethnic and subcultural identification; frequency of interaction with friends; community ties; number and nature of non-family roles), and personal resources (e.g., health; well-being; personality variables). Perhaps the most outspoken contemporary advocate of grandparenthood as a vital intergenerational connection, Kornhaber identifies a somewhat different set of determinants of grandparent role behavior. He points to societal attitude toward grandparenting, and to personality altruism. He also identifies the following earlier-life, intergenerational determinants of grandparent behavior: (a) the individual's experience as a grandchild, and (b) the individual's parents' grandparenting behaviors. These last determinants remind us that as a relationship in which most people participate for most of their lives, grandparenthood rests on a foundation that is established, inalterably, in childhood. A given adult's grandparenthood is determined both by circumstances that are in effect in adulthood, and also by those that were influential during childhood. For better or worse, the grandchildhood experiences of today's children will influence the grandparenthood they are able to enact two generations hence.

Meaning

Attention to behavior alone ignores the meaning and importance of the grandparent role to grandparents. Neugarten and Weinstein used their interview data to specify five categories of grandparenthood meaning: source of biological renewal, opportunity to succeed in a new emotional role, teacher–resource person role, vicarious achievement, and remote role. Examining grandparenthood meaning as a product of social and personal forces, V. Wood and J. Robertson designated four grandparenthood role types, representing high versus low dichotomizations of each dimension. These early typologies share the property of categorization (e.g., a grandparent's style is either formal or fun seeker; the meaning he or she finds in grandparenthood is either vicarious achievement or source of biological renewal).

Based on interviews with 286 grandparents, psychologist H. Kivnick deductively derived five different

dimensions of grandparenthood meaning: centrality, valued elder, indulgence, immortality through clan, and reinvolvement with personal past. Unlike earlier typologies, these dimensions were conceptualized as comprising, all together, the overall meaning a given individual finds in grandparenthood. Rather than being categorized as experiencing grandparenthood in terms of centrality or indulgence, for example, an individual is assumed to experience grandparenthood in terms of all five dimensions; he or she may be scored from high to low on each dimension.

Life cycle theorist E. H. Erikson and his colleagues J. Erikson and H. Kivnick describe the psychosocial theme of generativity and stagnation as comprising the experiences of caring, nurturing, and maintaining. After middle adulthood's direct 'responsibility for the maintenance of the world,' generativity comes to involve more indirect nurturing, to promote the robust senses of caring, generational connectedness, and wisdom that are the goals of middle and later adulthood. An integral part of the generational cycle, grandparenthood offers a valuable opportunity for grandparents to revisit their own capacities to nurture and to care, while, at the same time, enriching the essential generativity received by grandchildren.

Kornhaber and Woodward highlight reciprocity in the ways grandparent and grandchild roles are linked to the developmental needs of both generations. Shared time, shared place, shared activities, commitment to family – all these are crucial in establishing and maintaining a grandparenthood relationship. All are also crucial in accomplishing age-appropriate tasks related to generativity for both grandparent and grandchild. Qualitative exploration of grandparental units provides empirical evidence for the existence of generativity in the grandparenthood relationship. Although interviewed grandparents did not articulate consciously generative goals, enduring positive relations with grandchildren and feelings of success with intergenerational family life were interpreted as indications that grandparenthood facilitates developmental generativity. By maintaining strong affectional ties and mutually acceptable levels of association with grandchildren, grandparents seem to be able to balance their conflicting needs for contact and independence, for family identity and individuality, for personal usefulness and freedom from responsibility.

Role Ambiguity and Grandparenthood Career

Failing to find powerful associations between grandparenthood and diverse measures of grandparent well-being, researchers have long described the grandparent role as a relatively unimportant component of later life. Sociologists L. Burton and V. Bengtson note that grandparenthood conforms to Rosow's definition of a tenuous role (i.e., a definite social position with only vague behavioral guidelines). In the macrosocial structure, grandparenthood cannot be considered a functional role. Its presence or absence is thought to have no definitive effect on whether or not 'society is possible.' It carries no universal expectations governed by Durkheim's 'collective conscience.' It assumes a comparably idiosyncratic character within the microstructure; regardless of family expectations, a grandparent may choose to engage or not to engage in any role behavior.

Like that of parent, the role of grandparent follows a career trajectory, and the course of its interactions changes in predictable ways. The career begins with the news of imminent grandparenthood (i.e., of the imminent acquisition of a new status). This anticipatory stage is structured by expectations that are generally vague but enjoyable. The role at this point is titular. Behaviors include telling the news to friends and other family members, and, in some cases, assisting with preparations. Consistent with Kornhaber's new social contract, anticipatory grandparents speak of waiting to see how these new relationships will develop far more often than they describe assuming an active role in creating or structuring them.

Research suggests that once the grandparenthood bond is established in childhood, it remains fairly stable throughout the rest of the life course. Nonetheless, the grandparent career moves through distinct periods. During the grandchild's preschool and elementary years, grandparents typically enjoy their most frequent contact. As grandparent and grandchild spend time together, the grandparent's role broadens and deepens. These are the years Cherlin and Furstenberg refer to as the 'fat years,' during which grandparents can becoming living ancestors and historians, treasured companions, and role models. During the subsequent 'lean years' of the grandchild's adolescence, contact typically decreases and – if a solid bond has been established in the previous stage – the grandparent typically becomes a source of assistance and advice in times of expressed need. The final period of grandparenthood is the longest, beginning when the grandchild enters adulthood and grandparents, like parents, must learn to let go. Greatgrandparenthood, with its primarily symbolic significance, may be seen as a separate phase in this long final period.

Timing

Neugarten's concept of social time – society's age-grade system for appropriate progression through life's roles – influences the grandparenthood experience.

The significance of grandparenthood timing is particularly important in view of the fact that becoming a grandparent is a countertransition (i.e., a role change dependent on a transition initiated by another family member). The timing of grandparenthood hinges both on the age at which the individual became a parent, and also on the age at which his or her children reproduce for the first time. Grandparents have no control over the timing of this countertransition; they must live with the timing forced upon them.

Normative in middle age, first-time grandparenthood is seen as on time when it occurs between the ages of 42 and 57. Research indicates that assuming the grandmother role significantly early (ages 25–38) may result in 'crisis accumulation,' in which the combined demands of children, grandchildren, work, and other generational family members make a woman vulnerable to 'role overload.' In addition to concrete behavioral demands, early grandmotherhood may precipitate tension in a young woman's view of herself, and it may trigger conflict in the familywide system of cohesion and social support. Defending against all these tensions, some early grandmothers explicitly refuse to engage in the grandparent role. By contrast, research suggests that on-time grandmothers avoid the strains of off-time transitions and feel good about their grandparenthood timing.

Instrumentality

Despite contemporary norms of grandparent noninterference, the role does involve a variety of instrumental expressions. As 'family watchdogs,' grandparents respond to obvious need in the next generations by providing service. Reciprocally, grandparents often receive essential service from intergenerational family members. The last years of the twentieth century witnessed a dramatic shrinkage of societal economic resources, and a corresponding expansion of the demands placed on extended family members. It is therefore not surprising that the bulk of current grandparenthood research concerns instrumental service provision.

Grandparent Caretakers Grandparents provide care for their grandchildren within a range of structures. Some provide regular day care while the parents are at work. Others provide primary care while coresiding with the grandchildren, and, perhaps, with their parent(s), as well. Still others acquire legal custody of the grandchildren (*see* Caregiving and Caring). Traditionally, the Black community has emphasized support within extended kin networks. Indeed, Black children are much more likely than Whites or Latinos to live in grandparents' homes. However, since 1980 it is White children who have been moving into grandparents' homes at the greatest rates.

Although many grandparents function as their grandchildren's sole caregiver, parents of adolescent mothers often share caregiving responsibilities with coresiding daughters who must now balance the demands of parenthood with the developmental tasks of adolescence. As these families' most consistent providers of care and support, grandparents serve as both role models and caregivers to both mother and grandchild. Grandparents play an important role in assessing the mother's competency to care for her child, often taking over when they judge the mother to be incompetent. For young mothers, grandmothers tend to provide the most and highest-quality support when the mother lives with them, and when the grandchild's father is less involved. Young Black mothers are far more likely than Whites to coreside with grandmothers. For older mothers, grandmothers are likely to be most effective caregivers in noncoresidential situaions. Grandmothers seem to experience most caregiver satisfaction when they do not have preschool children of their own, and when they, themselves, receive support from a partner or financial assistance such as Aid to Families with Dependent Children (AFDC).

When grandmothers provide daily child care, the grandchild's mother or father or both are usually working full time. Such grandmothers want to help the parent(s) financially, and they would rather not leave their grandchildren in paid day care or at a sitter's house. In such circumstances, grandparents attempt to support the middle-generation nuclear family and help keep it intact.

Under other circumstances (e.g., child abandonment, neglect, or abuse; parental mental or emotional problems; parental death; parental incarceration; parental drug addiction, particularly to crack cocaine), the middle-generation nuclear family is so badly disintegrated that grandparents intervene both to provide care and, when necessary, to assume legal responsibility for the grandchildren. Some of these negative circumstances may arise without warning, such as a young mother's sudden death or incarceration. Others arise as a result of ongoing parent–grandparent negotiation. Still others develop over time, until the grandparent decides that personal intervention is necessary.

Most caregiving grandparents experience emotional, physical, and financial strains associated with their caregiving roles. If their primary caregiving is to be long term or permanent, grandparents may worry about living long enough to raise their grandchildren

to adulthood. Others are concerned about keeping up with the grandchildren's school, social, and physical activities. Still others are anxious about possible psychological harm to grandchildren who have been abused by their parents.

Parental crack cocaine addiction creates unique concerns for grandparent caregivers. Many fear for their own safety and security, as well as their grandchildren's. Some worry that their addicted children will steal their money or property to buy drugs, perhaps using physical violence to do so. Others experience anxiety about the burglaries, drive-by shootings, and dangerous automobile traffic that pervade neighborhoods beset by drug trafficking. In addition, these grandparents anticipate the financial and emotional drains of having to provide care for multiple kin. With respect to the grandchildren, grandparents worry that despite their best caregiving efforts, the children will inherit their parents' addictions.

Grandparents undergo a variety of life changes when they assume parental responsibility for the grandchildren. Most often reported are the negative changes. Grandparents who quit jobs to become full-time caregivers may miss contact with co-workers; most regret decreased opportunities for socializing with friends and confidantes. Many feel cheated of personal space, privacy, and freedom. Others experience moving backward in their lives. Still others find that renewed caregiving responsibilities strain their once postparental marriages. Negative health-related outcomes may include physical conditions such as heart attacks, strokes, diabetes, and arthritis. Alcoholism, increased smoking, and depression and anxiety have all been reported as negative emotional consequences (*see* Alcohol and Drugs; Depression).

Not all the changes associated with full-time caregiving are negative. Some caregiving grandparents develop new friendships as they identify with other people who share their current situation. Where some experience marital strain, as noted above, others report enhanced marriages or relationships as the grandchildren foster improved communication and increased time together between partners. Although health problems plague some grandparent caregivers, others experience improved health as they adopt more nutritious diets and engage in physical activity with the grandchildren.

Within the family context, grandparent caregivers may experience a variety of important satisfactions. Those who are displeased with the way they raised their own children may welcome what they regard as a second chance at parenting. Others value the opportunity to nurture their family line. Many treasure the gifts of companionship and love they receive from their grandchildren. Most grandparents who provide caregiving in place of ineffective parents are proud to see themselves as actively creating positive change in an otherwise deteriorating family cycle.

Reciprocal Caregiving The relationship between American elders and their families is characterized by a 'generalized reciprocity' across generations. Over the life course, family members exchange affective and instrumental support as needed, effectively making deposits and withdrawals from what T. Antonucci refers to as a lifelong bank of support. Not only do grandparents provide assistance in times of family crises. They receive needed care and support, as well (*see* Social Networks, Support, and Integration).

Although grandparents and their adult grandchildren seem to share expectations of turning to one another for whatever support may be needed, grandparents both expect and receive more emotional than instrumental support from their adult grandchildren. And grandparents generally perceive that they receive more from their adult grandchildren than they currently provide in return. These findings correspond to the literature on relations between adult children and their aging parents. Where instrumental support is provided, it comes most often from female members of the middle generation.

Divorce Middle-generation divorce is one of the major family disruptions against which grandparents are seen as providing continuity. During such times of crisis, older persons' importance to the family may increase significantly. Johnson reports that after a divorce, most grandparents try to provide instrumental assistance (e.g., money, babysitting, and other services) and emotional support to parents and grandchildren. Grandparents may be in a unique position to offer the grandchildren an emotional haven. In some cases, grandparents assume parental responsibility for a number of years, while the biological parent retains or struggles to regain legal custody.

Divorce can precipitate both increases and decreases in grandparents' contact with their grandchildren. Increases typically result when the grandchildren move to a closer geographic location, when grandmothers provide child care for custodial daughters who reenter the workforce, and when hostile parents are removed from the grandchildren's daily lives. Decreased contact typically results from distant geographic moves and from unresolved grandparent–parent conflict in the wake of the divorce.

Particularly after divorce, parents have the power to facilitate or prevent grandparent access to grandchildren. Although all states (excluding the District

of Columbia) have passed grandparent visitation rights statutes, the matter of postdivorce grandparent contact is far from settled. Proponents argue that the grandparent–grandchild bond is uniquely precious, and that it is in the child's best interest for the court to enforce visitation rights. Opponents counter that court-ordered grandparent visitation interferes with appropriate parental authority. Even in the absence of conflict, non-custodial parents may be reluctant to share their child visitation time with grandparents.

In addition to depending on family dynamics, grandparents' roles during and after divorce can vary with grandparent age and lineage. Older grandparents are more likely to experience disabilities that prevent them from offering help and assistance. Even before divorce, younger grandparents tend to be more active and to have more contact with grandchildren. Younger grandparents may also be more tolerant and less judgmental, and they may therefore be more welcome in postdivorce households. Although paternal grandmothers are generally described as having less contact with and providing less assistance to postdivorce grandchildren, many paternal grandmothers make a point of maintaining contact with their former daughters-in-law who, in turn, permit access to the grandchildren.

Grandparent Satisfaction and Well-Being

Research finds that grandparents generally report satisfaction, pride, and pleasure in grandparenthood. No one variable emerges as critical in determining level of satisfaction. Rather, chronological age, timing of role entry, religious affiliation, lineage, and frequency of contact all seem to contribute. Despite expressions of role satisfaction, interviewed grandparents frequently mention disappointment and disapproval in connection with particular relationships. They deny wanting to be more involved with their grandchildren, despite psychologist J. Thomas's finding that grandmothers and grandfathers who experience most satisfaction are those who have most responsibility for helping with grandchildren. These contradictions suggest that in circumstances of perceived interpersonal powerlessness, grandparents may be working hard to make the best of existing situations. They feel they can do little to influence particular relationships. What they can influence is the satisfaction they allow themselves to experience in grandparenthood, as a whole.

Apart from grandparenthood satisfaction, per se, researchers have tried, with little success, to explore the influence of grandparenthood on grandparents' psychosocial well-being. There appears to be some disagreement about whether higher grandparent involvement with grandchildren's families is associated with increased grandparent morale (as a function of providing essential service) or decreased morale (as a result of being the only available helper when a child's family is in trouble). The nature of existing research does not permit investigation of the proposition that grandparent involvement may be associated with increased morale among grandparents who might otherwise be even more depressed and despondent.

Psychologist V. Kivett suggests that the grandparent role may provide an important sense of psychological security for both Black and White grandmothers. Kivnick proposes that grandparenthood offers a valuable opportunity for the grandparent to make progress in the essential psychosocial work of middle and later adulthood. As such, the role should be expected to enhance grandparent well-being. Burton identifies psychological rewards experienced by grandmothers who serve as surrogate parents. Psychologist R. Pruchno proposes an elaborate model for evaluating the psychological well-being of grandparent caregivers, as a function of stressors (e.g., child-care demands; competing role demands; life-event demands), resources (personal; family; social; environmental), and perceptions of relative satisfaction and burden.

Grandparenthood to Younger Generations

Elusive Influence

Research on grandparent influence generally begins with an impression that grandparents are important in the lives of grandchildren, fails to confirm this importance, and concludes with a perflexed unwillingness to dismiss, altogether, the value of grandparents. Scholars have begun to resolve this contradiction by suggesting that grandparents' importance in families may not reside in observable behaviors or in other easily measurable variables. Rather, their importance may be far more elusive, related to a variety of symbolic meanings and influences that are not easily captured with the tools of quantitative social science.

Perhaps, too, grandparents' major influence may blossom over the life cycle and may be all but undetectable during the 'fat years' that are most often studied. For example, research finds little evidence that grandparents' values influence the values of their grandchildren. However, much of this research assesses particular family values, as they exist in grandchildren's minds during childhood. Where do children learn those values that underlie a lifetime of behavior (e.g., commitment to competence at a craft; rootedness in history; commitment to family; understanding generational connectedness)? Perhaps

these values are learned in the context of an ongoing relationship with grandparents. It is not unreasonable to expect that meaningful childhood relations with grandparents contribute to positive adjustment and mental health in adulthood, or to lifelong satisfaction in cross-generational relationships. The fact that these influences are not detected by conventional research methodologies neither confirms nor denies their existence.

Symbolic Influence

Sociologists identify the following symbolic functions of grandparents within families:

1. Stabilize the next generation by providing a buffer against its mortality.
2. Catalyze family cohesion.
3. Moderate intensity of nuclear family life by providing a sounding board and a mediator for both generations.
4. Serve as 'family watchdogs,' maintaining a latent observation and protection service that can become active frontline management when necessary.
5. Symbolize family continuity across generational past, present, and future – particularly during times of family disruption.

Family practitioners agree that grandparents can be crucial to the effective functioning of families in the following ways:

1. Reduce intensity of intergenerational conflicts by prompting maneuvering around touchy issues.
2. Mediate and interpret between two generations.
3. Provide emotional and financial support for parenting.
4. Serve as a nexus of family connections.
5. Relate to parents in a way that facilitates marital adjustment.
6. Support parents during times of marital conflict.
7. Modulate family life experiences on the basis of accumulated wisdom.
8. Expand the age range and number of available role models for family members, modeling adulthood and old age for grandchildren, and modeling grandparenthood itself for both children and their parents.

Developmental Influence

Despite disappointing empirical results, grandparent researchers remain convinced of the importance of grandparents for grandchildren. Emotional attachments between grandparents and grandchildren have been described as uniquely unconditional because of this relationship's exemption from parent–child intensities and responsibilities. Grandparents can serve as constant objects in the child's life, as 'Great Parents' who provide a secure and loving adult–child relationship that is next in emotional power only to the parental bond.

Pastoralists D. Conroy and C. Fahey point out that grandparents have a great deal to do with the initial development of a child's view of life. Kornhaber asserts that children's complete emotional well-being requires a direct, and not merely derived or symbolic, link with their grandparents. In the absence of this relationship children experience a deprivation of nurturance, support, and emotional security. Anthropologist M. Mead maintains that intergenerational family relationships, exemplified by grandparenthood, are absolutely essential to the child's development of his or her own uniqueness, wholeness, and cultural and historical continuity.

Young Adult and Adolescent Grandchildren

If grandchildren's preschool and school years signify grandparenthood's 'fat period' to grandparents, the children's adolescent and young adult years signify increasingly lean periods. How do grandchildren experience these distinct relationship periods? Scholars report that the amount of grandparenthood contact during childhood directly affects the type of relationship grandchildren and grandparents later maintain. They further suggest that when close, intimate grandparenthood relationships are formed during childhood, both grandparent and grandchild continue to nurture the attachment throughout life. Nonetheless, the literature does not consistently support the view that grandparents remain significant throughout grandchildren's adolescent and young adult years.

Secondary data analysis indicates that adolescent children of single mothers benefit from a grandparent's presence in the home. Because adolescents in single-parent homes are especially independent, they are likely to be in particular need of the supervision and control available in an extended household. Furhermore, a grandparent's presence in a family that otherwise tends to be non-hierarchical may reinforce generational boundaries, thus maintaining the benefits of hierarchical structure.

Based on self-report questionnaires, the overall picture of grandparenthood to adolescents seems to be one of frequent, dynamic intergenerational involvement. High school students report viewing their grandparents as confidantes and companions. They say it is enjoyment of contact, rather than

family obligation, that motivates them to maintain these relationships, and they describe brief conversations and important discussions as replacing childhood's largely recreational visits. Young-adult grandchildren describe relationships with grandparents as extremely important; they indicate that contact frequency affects the solidarity, not the importance, of these relationships. However, these findings conflict with longitudinal data indicating that grandchildren's transition from childhood to adolescence prompts a more dramatic change in grandparenthood relationships than any other grandparent or grandchild life transition.

Cross-cultural Grandparents

Relation to Cultural Values

Mainstream Euro-American culture has long been characterized by its overwhelming emphasis on the principles of autonomy and individualism. Under conditions of economic hardship, individual wishes and aspirations are subordinated to the family obligations that ensure survival. But in times of relative security, behavior is governed by individual independence, self-reliance, and freedom from the constraints of commitment. This underlying value system is absolutely consistent with Cherlin and Furstenberg's description of contemporary American grandparents as paying far more attention to preserving independence (their own, their children's, and their grandchildren's) than to promoting long-term or deep-seated emotional well-being.

Little research is available to describe grandparents in diverse American subcultures that are organized around family commitment, group interdependence, or respect for elders. We might expect Native American grandparents, for example, to be more concerned with a given relationship's impact on a grandchild's long-term development than with its momentary enjoyment value. We might expect Hmong-American grandparenting behaviors to be determined more powerfully by their effect on overall group well-being than by their protection of individual freedom.

African-American Grandparents

In view of traditional African emphasis on individual interconnectedness with the group, Kivett's finding that grandparenthood is more salient in the Black community than the White should not be surprising. Black grandparents assume parental responsibility for grandchildren far more often than White grandparents. To a far greater extent than White families, Black families demonstrate regard for older adults, propensities to protect the frail and dependent, and expandable household boundaries as dictated by the needs of kin and significant non-kin. Indeed, 'fictive' or 'pseudo' kin are important members of many Black families. These people are regarded in kinship terms, they are accorded many of kinship's rights and statuses, and they participate fully in informal support networks. Whereas only 8% of Anglos in Bengtson's cross-cultural study report having raised children other than their own biological offspring, nearly half of the Black adults over 60 report having raised fictive children and grandchildren.

Research seems to confirm some stereotypes about Black intergenerational families while failing to confirm others. Burton and Bengtson acknowledge the important tradition represented by Black grandmothers in African-American culture. However, they describe the familiar view that Black women regard children as God's blessing as a holdover from slavery, rather than a cultural tradition. They report that for most of their respondents, off-time grandmotherhood may represent both a symbolic and an instrumental crisis. That is, for these women, too-early accession to this lineage role creates conflicts both in their view of themselves, and also in their family system of cohesion and social support.

African American scholar R. Taylor notes that aged Blacks have significant and varied family roles, maintaining extensive contact with children and grandchildren. Qualitative studies point to the importance and critical nature of the family for the functioning of elderly African Americans and, reciprocally, to the importance of these elderly for the survival of African American families. On many socioeconomic indicators older Blacks represent one of the most severely disadvantaged groups in our society. Their family roles are particularly important, both in view of their special needs for assistance, and also in terms of their unique capacities for contribution.

Latino Grandparents

In Latino culture, elders are esteemed for the wisdom that is reserved for them, alone. Within neighborhoods elders act as part of a grapevine of social control. Within households, their presence helps reduce anxiety resulting from such nuclear family stresses as a child's illness, divorce, or overtime work for parents. Hispanic tradition supports the view that elders are teachers who participate in cooperative efforts. Because their wisdom is valued, physical decline does not diminish the family contributions of aged Latinos as it does among Anglos.

Gerontologist C. Garcia points out that extended Latino families must be viewed in terms of function (interaction and exchange) rather than structure (residence). By and large, Latino grandparents live with a child's family. But because a grandparent has many children and because he or she can only live in one household, most middle-generation households do not structurally include grandparents. Functionally, however, Garcia reports that every household views grandparents as active members.

Studies of Chicano grandparents find that grandmothers play several roles:

1. child rearers
2. participants in family decision making
3. religious advocates and teachers
4. participants in a female network of healers.

Both grandmothers and grandfathers value their caregiving activities, considering themselves equally responsible for child rearing. They view their most important task to be teaching the grandchildren Spanish, traditional customs, and morality. Rather than stressing autonomy, they emphasize interdependence and cooperation with their families.

Latino culture does not regard productive work in one's occupation as life's central task. Cultural tradition also values leisure, and it regards extended family relationships as an important source of personal identity. As a result of the family being so highly valued, aged Latinos do not seem to undergo a dramatic role change upon retirement.

Future Outlook

Research

Grandparenthood has been properly explored within the disciplines of anthropology, sociology, history, family studies, psychology, psychiatry, gerontology, social work, public policy, and cultural studies. Each discipline views the world through its own theoretical lens, focusing on its own issues of concern, utilizing its own research tools, reporting in its own terms. Over the less than 50 years that grandparenthood has been formally studied, historical trends have influenced not only the role and relationship under investigation, but also the goals, foci, and strategies of research within every involved discipline. Accumulated disparate findings are not easily synthesized into a coherent body of knowledge. Thus, after decades of research, our understanding of grandparenthood – family relationship, ascribed status, social role, psychological object, source of personal meaning, and more – remains fragmented. Attempts to integrate risk confounding description, explanation, prediction, and advocacy.

Quantitative research methods have focused our attention on a wide array of measurable demographic, behavioral, and psychological variables. However, because measurable variables are not necessarily valid operationalizations of the concepts under investigation, descriptive findings too often appear superficial and removed from the lives of the real people who are grandparents. Grandparenthood meaning, importance, and influence remain elusive.

Recent qualitative investigations of cross-cultural grandparents have begun to provide valuable insights into grandparenthood's complexity, and to suggest lines of inquiry for mainstream grandparenthood, as well. This work suggests that the values of particular cultures (concerning family, wisdom, work, aging, and more) are integrally related to grandparenthood and must be explored further. It is to be hoped that qualitative research will continue to make progress in identifying, understanding, operationalizing, and quantifying meaningful variables, and in building theoretical concepts that will be amenable to traditional, quantitative social science research.

As a phenomenon that is both intergenerational and lifelong, grandparenthood must be explored with research strategies that are sensitive both to intergenerational and family systems issues, on the one hand, and to life cycle development issues, on the other. Related to both science and practice, grandparenthood research must be conducted with an eye both to building knowledge and also to improving practice and policy. Areas of special current concern include grandparents as caregivers and as recipients of family-care, grandparenthood in the expanding life period of 'old-old' age, and grandparents as part of our society's complex system of racial, ethnic, and cultural relations.

Practice

Discussions of contemporary American grandparenthood fall on a continuum. At one end we are called to return to the 'good old days' of strong family ties. At the other end we are reminded that progress has its costs, and that strong, involved grandparenthood may be one of them. Several important practical issues underlie this entire continuum.

Grandparenthood conflicts and dilemmas may be seen as a metaphor for all family relationships. Every family bond involves a self and an 'other,' whether that other be an individual or a group. Establishing and maintaining bonds requires a constant balancing and rebalancing of concerns for self with concerns for other. In addition, maintaining family bonds over

time requires a balance between perceived well-being now, and anticipated well-being over a life cycle that involves both personal and generational futures. To the extent that we seek to understand or influence grandparenthood, we must do so in the context of these essential balances and their parameters.

American society is constantly evolving. We must remember that just as grandparenthood has changed with past historical shifts, so it will change with the social, economic, and cultural shifts of the present and future. Contemporary grandparenthood may be an understandable reflection of intergenerational affection without interference. But grandparenthood will not necessarily reflect these same values in the future.

Family scholars inform students that maintaining viable intergenerational ties requires considerable care and effort; grandparents have long admonished grandchildren that 'You get out of something what you put into it.' Grandparenthood as an institution may, indeed, reflect sociohistorical developments. But within any given family, people are free to make of this relationship as much or as little as they choose. American societal norms may encourage individualism and non-interference. But individual families and communities are free to balance these values with cooperation and respectful long-term responsibility. Grandparenthood, as a phenomenon, will continue to reflect large-scale societal currents. But individual people and families need not bob, like dinghies on the waves. The participants in any particular grandparenthood relationship can work to make that relationship meet the needs they decide are important.

See also: Alcohol and Drugs; Caregiving and Caring; Depression; Economics: Society; Social Networks, Support, and Integration.

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H

Health Care and Services

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Glossary

Geriatrics – The practice of care for frail older people and represents the intersection of chronic disease care and gerontology.

Managed Care – Some method by which a fixed sum is paid to cover a person's health care costs for periods of time, and efforts are made to deliver that care as efficiently as possible.

Successful Care – Making someone better and/or slowing the rate of deterioration.

Introduction

Health care for older people involves managing chronic illness. In essence, geriatrics represents the intersection of chronic disease care and gerontology. Diseases present differently in older persons, and their treatment is complicated by the presence of impairments in other domains, such as affect, cognition, and economics. In the United States, older persons are the only group covered by a universal health care insurance system. Nonetheless, there remains substantial geographic variation in access to care. In general, older people still suffer from ageism; decisions about what care they should receive is influenced by beliefs about what is age appropriate.

Dominance of Chronic Illness

The story of health care for older persons is inexorably linked to chronic disease. Indeed, chronic disease is the dominant factor in health care for all ages, but its predominance is especially high for older persons. If for no other reason than because such conditions accumulate with time, older people are disproportionately heavy users of health care, largely because they have a heavier illness burden. **Figure 1** shows the distribution of chronic illness among elderly persons. In the United States, elderly persons are the only demographic group that has virtually universal health coverage, under Medicare.

Addressing chronic care effectively implies drastically changing the current health system, which was developed to address primarily acute problems. The implied reformation addresses a wide range of aspects of care, including the definitions of concepts such as prevention, the role of patients, and even time. Prevention is best thought of in terms of avoiding major catastrophes. In effect, good chronic disease care will handle problems proactively to prevent emergency room visits and hospitalizations.

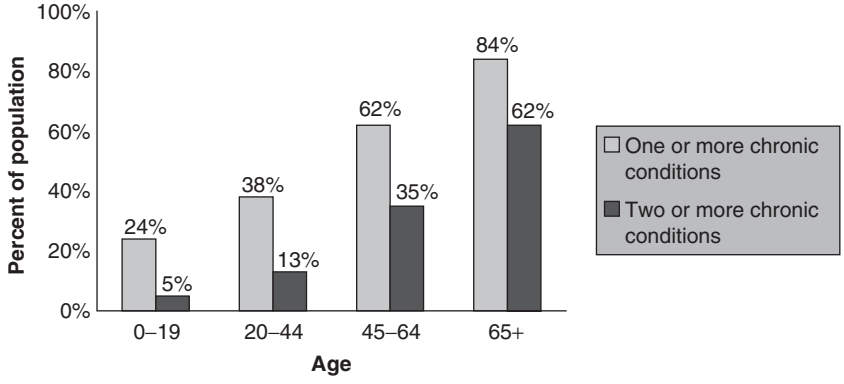

Figure 1 Percent of US population with chronic conditions by age. From Partnership for Solutions (2002).

It is unrealistic to think about managing chronic disease without actively involving patients in their own care. They are the ones who must deal with the disease every day. The challenge lies in determining how to create a productive partnership between patients and their clinicians. Programs designed to give patients a greater sense of empowerment have been promising. Another approach encourages patients to record systematic observations on defined parameters that reflect the clinical course of their diseases and to notify their clinicians when the observed course deviates from what had been expected.

Time too takes on a new meaning, beyond that implied by the term 'chronic.' In effect, chronic care means thinking in terms of investments. One provides active primary care with the expectation of recouping that effort in terms of subsequent care avoided. Focusing attention on high-risk periods, such as immediately after a hospital discharge, can pay dividends. Nurses working with patients in these situations can improve compliance with postdischarge regimens and prevent subsequent readmissions. Scheduling encounters need to be overhauled. Instead of seeing patients on a fixed time schedule based on a loose expectation of when another assessment is needed, visits should be triggered by patients' actual courses. They need to be seen when their condition deviates from the predicted path; then they need to be seen quickly to treat the problem before it becomes serious.

Professionals can be quite varied. Nurse practitioners have been shown to be very effective in managing chronic problems. They can work independently, or they can team with specialists to allow them to address the organ of interest while the nurse attends to the whole person.

Perhaps one of the most difficult issues surrounding chronic illness is the definition of successful care. Because the general course of chronic illness is gradual deterioration, success is not simply making someone better; it may be slowing the rate of deterioration. However, establishing that effect is difficult in the absence of some point of comparison. What would have occurred in the absence of good care? Such comparison groups are rarely available. Instead, we must rely on statistical analyses, but these data are too theoretical to be attractive or convincing. The logical support for chronic care is information technology. Systems that can show changes over time and that can notify clinicians about changes in a patient's condition can play central roles in proactive care. Because many different professionals may be involved in the care of some frail older people, ways to share information should be useful. The utility would be enhanced if the information were available in a structured format that allowed systematic collection.

Care of frail older persons frequently involves coordinating the medical and social components of care. Most older people requiring long-term care have serious underlying medical problems. Attention to these problems will affect functioning and quality of life. However, life consists of more than having good medical care.

The goals of effective chronic disease care can be summarized as follows:

1. Manage the disease as well as possible to reduce the extent and frequency of exacerbations.
2. Prevent (or at least minimize) the transition from impairment to disability, and from disability to handicap.
3. Encourage the patient to play an active role in managing his or her disease but avoid allowing the disease to become the dominant force in the person's life.
4. Provide care in a culturally sensitive manner.
5. Integrate medical care with other aspects of life and care without medicalizing those aspects.

Table 1 summarizes a number of innovative approaches to addressing the problems associated with managing chronic disease. Most have shown at least some benefits. Ironically, the one area that has shown the fewest positive effects is the one most actively embraced, case management. Part of the problem can be traced to the confusing way this term has been used. In fact, there are many different types of case management, often directed at different goals. At least five variants can be identified: eligibility management, care coordination, utilization management, disease management, and chronic care management. **Table 2** contrasts these variations on the case management theme.

Geriatric Paradigm

Geriatrics is the practice of care for frail older people. The epitome of geriatrics is treating multiple interactive problems that cross domains. In essence, geriatrics represents the intersection of chronic disease care and gerontology. Clinicians caring for older persons need to understand that diseases present differently in older persons, and their management is complicated by the presence of other factors. Older people take more medications, and hence are at greater risk of drug interactions. Older people may face problems in other sectors of their lives, such as their social roles, their economic status, their cognition, and their affect, which complicates treatment for specific health problems.

Table 1 Effectiveness of chronic disease care interventions[a]

	Satisfaction	*Function*	*Utilization*	*Costs*	*Mortality*
Interdisciplinary home care	+	+	+	+	
Self management	+	+	+	+	
Group care	+		+	+	
Home hospital	+		+	+	=
Disease management			+	+	
Professional dyads in nursing homes			+		=
Acute care for the elderly hospital wards	+	+	=	=	=
Geriatric evaluation and management	+	+	−	−	=
Transitional care	=	=	+	+	=
Case management		=	=	=	=

[a] +, indicates a superior outcome associated with the experimental form of care; −, indicates a worse outcome associated with the experimental form of care; =, indicates similar outcomes for the experimental and the comparison forms of care; an empty cell indicates that the outcome was not measured.

Table 2 Variations on case management

	Typical provider	*Aims*	*Implications*
Eligibility management	Social worker or nurse	Assessment to see if client reaches threshold for eligibility Care plan Implementations	Cursory monitoring for change in status that would affect eligibility
Care coordination	Social worker or nurse	Structured assessment to indentify needs Care plan addressing each need Arrange services to meet each need Follow up to assure services are delivered Re-assess periodically and adjust care plan	
Utilization management	Usually a nurse	Identify high-volume/high-cost cases Work with high users to change clinical course • Monitor intensively • Counsel to encourage compliance • Seek ways to prevent problems • Flag charts to alert clinicians	
Disease management	Usually a nurse, possibly an MD	Focus on a single disease Provide reminders Counseling Monitoring	Usually not coordinated with primary care
Chronic care management	Nurse or nurse practitioner	Establish expected clinical course Monitor salient parameter for each condition followed • Patients can do most of the monitoring • Communicate with clinicians by phone, web • Intervene when actual course differs from expected course • Indication for active intervention	See clients primarily when their condition changes significantly Can monitor many conditions simultaneously Can address function as well as diseases

Medical problems may manifest differently in older persons than in younger ones for two reasons. First, older people often suffer from multiple diseases. A change in one of these may become lost in the noisy background of others. Whereas in a younger the person the onset of new problems may be distinct, like a mesa in the desert, in an older person an exacerbation, or even a new onset,

may be as hard to detect as a new peak among the Alps.

The second relevant concept is based on the changes associated with aging. In general, age-related physiological changes are most evident in dynamic measures. Older people do not react to stress as well as their younger counterparts. Most of the manifestations of disease, what we call signs and symptoms, are usually not the effects of the disease per se, but the body's reaction to the stress produced by the disease. Little wonder, then, that older people would not show the classic symptoms of a disease, but instead some muted or general response. Whereas a younger person having a heart attack might complain about chest pain, an older person might present with confusion. This same symptom could be caused by pneumonia or a drug reaction. Thus, diagnosing disease in older people is often a much more difficult feat than with younger patients.

Diagnosis is hindered still further by communication problems created by problems with vision, hearing, or dementia. On top of these communication problems, older people often suffer from multiple diseases, making it harder to distinguish the onset or change of a given symptom.

The basic technology of geriatrics is the comprehensive geriatric assessment (CGA). Experience has taught that exposing frail older persons to such an evaluation and then returning them to the same care environment did not sustain the effects. Gradually the concept of geriatric evaluation and management (GEM) evolved, which involved treating the patient for as long as needed to implement and sustain the necessary changes in the regimen. Few other approaches to care have been studied as thoroughly as CGA and GEM. Unfortunately, the results have provided a confusing and often contradictory story. Although meta-analyses imply that CGA is effective, the pattern is not consistent. **Table 3** summarizes the results of several inpatient CGA/GEM randomized trials. **Table 4** offers a comparable summary of outpatient studies. One of the largest and most recent studies was a multisite trial that involved both types of care. Although it was carefully targeted to patients who were deemed likely to benefit, it found scant effects. By contrast, a study that involved a simple home visit by a nurse practitioner to unselected older persons living at home yielded potent benefits, as did a preventive assessment by occupational therapists.

Sites of Care

A basic rule in geriatric care is not to confound the type of care received with the site of delivery. Clinical vocabulary has caused confusion by adopting terminology that defines care by where it is provided. Thus, we speak about inpatient and outpatient care, or nursing home and home care, as if those terms defined some level or type of care. In fact, the same care can be rendered in many settings. It is important to identify the critical elements of care and then ask what environmental supports are needed to provide it. The expansion of technology has meant that much care that formerly was restricted to institutions can now be delivered in outpatient settings or even at home. Laboratory tests that used to require specialized laboratories can now

Table 3 Inpatient geriatric assessment randomized controlled trials[a]

Author(s) Intervention	*Functional ability*	*Cognitive ability*	*Affect*	*Mortality*	*Satisfaction*	*Use of services*
Rubenstein *et al.* (1984)						
GEM, VA	+[b]	+	+[b]	+[b]	NE	+[b]
Allen *et al.* (1986), Becker *et al.* (1987), McVey *et al.* (1989)						
CGA, VA	=	NE	NE	NE	NE	=
Applegate *et al.* (1990)						
GEM	+[b]	=	=	NE	=	−
Fretwell *et al.* (1990)						
CGA	=	=	=	=	NE	=
Reuben *et al.* (1995)						
CGA, HMO	=	=	NE	=	NE	
Siu *et al.* (1996)						
CGA	=	=	=	=	−	=
Cohen *et al.* (2002)						
GEM, VA	+	NE	=	=	NE	=

[a] CGA, comprehensive geriatric assessment; GEM, geriatric evaluation and management; HMO, health maintenance organization; VA, Veterans Administration; +, outcome more favorable for intervention group; −, outcome more favorable for control group; =, outcome equal for GEM and control groups; NE, not evaluated.
[b] $P<0.05$.

Table 4 Outpatient geriatric assessment randomized controlled trials[a]

Author(s)	*Mortality*	*Functional ability*	*Cognitive ability*	*Affect*	*Use of services*	*Costs*
Tulloch and Moore (1979)	NE	=	NE	NE	Hospital admissions -	
Williams *et al.* (1987)	=	+	+	NE	Hospital days +[b] Hospital days +	Hospital +
Yeo *et al.* (1987)	−	+[b]	=	=	Home service −, NH − Primary care −[b]	NH + NE
Epstein *et al.* (1990)	=	=	=	=	Home services—dental, eyes, ear −[b] Primary care visit −[b]	NE
Rubin *et al.* (1992), Rubin (1993)	=	ADL = IADL +[b]	=	NE	Home service +[b]	Hospital +[b]
Burns *et al.* (1995)	+[b]	+	+	+[b]	Hospital use =	NE +
Silverman *et al.* (1995)	=		=	Anxiety, +	=	NE
Engelhardt *et al.* (1996)	=		NE	=	Primary care −[b] Emergency room +[b]	Outpatient −[b]
Boult *et al.* (1998)	=		NE	+[b]	=	=
Reuben *et al.* (1999)	+		NE	NE	NE	NE
Cohen *et al.* (2002)	=		NE	+	NE	=

[a] ADL, activity of daily living; IADL, instrumental ADL; =, outcome equal for GEM and control groups; +, outcome more favorable for intervention group; −, outcome more favorable for control group; NE, not evaluated; NH, nursing home.
[b] $P < 0.05$.

be performed by patients at home. Monitoring is possible from long distances.

Changing locations can save money. For example, by treating medical conditions of nursing home residents in the nursing home instead of sending them to the hospital emergency room (and likely hospitalization), one managed care organization saved substantial amounts of money and reduced the stress on the residents.

Organization of Care

The way care is organized affects how it is delivered and often what effects it produces. In many ways managed care would seem to be the natural vehicle by which to encourage better chronic care. Managed care implies some method by which a fixed sum is paid to cover a person's health-care costs for periods of time and efforts are made to deliver that care as efficiently as possible. Because the costs are paid up front, there are incentives for not spending money. Ideally, the per capita payment is calculated in an actuarially fair way, which reflects the expected costs of each enrollee based on their prior history and underlying health status. To the extent that good primary care prevents expensive complications, managed care provides a means to generate the capital needed to invest in an infrastructure that can produce better primary care, be it personnel or equipment.

Unfortunately, the promise of capitated care has not lived up to its potential. Given a weak case-mix adjustment payment system, it has proven easier to recruit fewer sick beneficiaries at an average price than to create the more cost-effective approaches of caring for those who need more attention. Indeed, there exists a strong disincentive to become good at chronic care for fear that those with the greatest needs will be attracted to such a program. If the case-mix adjustment is insufficient, the managed care organization may be financially disadvantaged by getting average costs for persons with greater than average needs.

In truth, every public health-care system (e.g., Medicare, the UK's National Health Service) can be viewed as managed care to the extent that it receives a fixed amount for care and is responsible for using the resources to the greatest advantage. In a universally covered system, there is nowhere to hide. Issues of case-mix payments do not apply, at least not in the aggregate, although some subcontractors may still require such a payment approach.

Variation

There is substantial geographic variation in the rates with which medical care is delivered. This variation among Medicare recipients in the United States has been extensively studied, because they have universal

Table 5 Rates of various surgical procedures per 100 000 (2002)[a]

	Cardiovascular						*Transplantation*		
	PTCA	*Stenting*	*CABG*	*Cholecystectomy*	*THR*	*TKR*	*Heart*	*Liver*	*Kidney*
Australia	130.1	125.6	81.9	233.9	141.6	118.7	0.4	*0.8*	3.1
Canada	158.2[b]	107.4[b]	76.5[b]	**245.3**[b]	*96.2*[b]	95.8[b]	0.5[b]	1.2[b]	**3.5**[b]
Denmark	91.6	69.3	68.9	129.4	182.5	81.5	**0.6**	0.7	3.2
France	157.1[b]	124.7[b]	*41.2*[b]	182.8[b]	187.5[b]	85.1[b]	0.5	**1.5**	3.8
Italy	81.8	*12.4*	48.4	172.9	127.3	*54.8*	0.5	0.9	2.8
Netherlands	86[b]		91.4[b]	120.8	137[b]	57.3[b]	0.5	1.2	*2.6*
New Zealand	86.2	63.2	102.4	*92.1*	109.6	55.2	*0.2*[b]	0.7[b]	3.3[b]
Switzerland	*77.8*	16.8	39.9	150	**192.5**	113.8	**0.6**	1	3
United Kingdom	*73.1*		44.2	95.3	152.1	91.8	0.4	1.1	3
United States	**415.9**	**185.5**	**106.5**[b]		119.4	**144.3**	0.3	1.2	2.9

Source: *OECD Health Data 2004: A Comparative Analysis of 30 Countries*–2004 edition.
[a] PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass graft; THR, total hip replacement; TKR, total knee replacement.
[b] Uses 2001 data.

coverage and a good data system. One study showed that both the effects of patient characteristics (e.g., race and ethnicity) and hospital market effects played a role in access to care among Medicare beneficiaries. Data provided by the Organisation for Economic Co-operation and Development (OECD) illustrates the variation across countries. These rates are based on populations, not just older persons, but the patterns can be safely extrapolated. **Table 5** shows the patterns for several surgical procedures. The variation among countries is not consistent across procedures. The United States has the highest rates among all three cardiovascular procedures, but the country with the lowest rate is different in each case (Switzerland for PTCAs, Italy for stents, and France for CABGs). Canada has the highest rate of cholecystectomies and the lowest rate of hip replacements. The United States has the lowest rate of hip replacements and the highest rate of knee replacements. For all procedures, the extent of variation is at least 2-fold; for some conditions, the rate is more than 10-fold (e.g., stenting). The United States is not the most active country in organ transplantation. Given that most of these countries (except the United States) have some form of universal access, the variation seems attributable to both formal and informal practice policies. One might speculate that the variation reflects the underlying rate of disease, but differences across procedures designed to address a similar problem suggest that other factors are in play.

Role of Primary Care

The key to chronic disease management is effective primary care. This level of care implies first contact care. In most developed societies, primary care is delivered by general practitioners (GPs), who care for persons living in the community (and sometimes in institutions, such as nursing homes). They provide the bulk of the care needed, referring to hospital-based specialists only when the case is too complicated for them to manage or when the patient needs more intensive hospital care. In most such situations patients can see a specialist only upon referral by a primary care clinician. The United States differs from most other countries in not having a formal schism between primary and specialty care. Instead, patients can choose whom they want to provide their primary care, who may well be a specialist. The decision is determined by supply and practice style. Such an arrangement creates substantial confusion.

Primary care physicians for adults are usually family practitioners and internists, although some women use their gynecologists in this role. As medicine has become more technologically oriented, fewer new physicians are entering primary care. The gap is being filled by nurse practitioners, nurses who are largely trained at the masters level to provide care to persons requiring primary care. There is substantial evidence suggesting that these nurse practitioners can provide primary care on a level equivalent to that provided by physicians.

Although many still consider geriatrics a specialty, in the United States it has also been proposed as a form of primary care. One problem with this formulation is that it places geriatrics in direct competition with the disciplines from which it would hope to draw referrals.

Changing Nature of Care

Since the 1980s the nature of medical care has undergone a remarkable transition. Various technologies that make the use of surgery less necessary

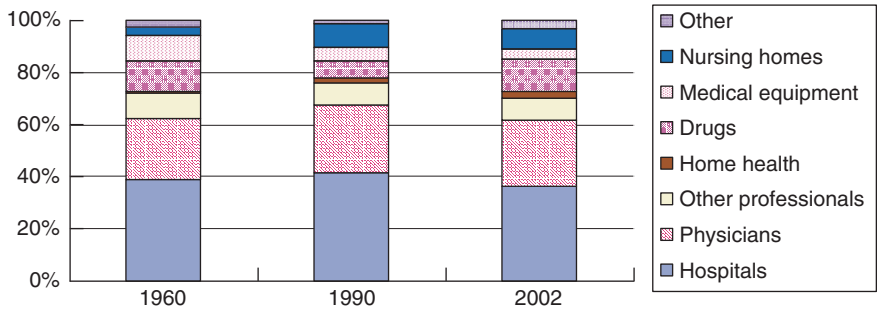

Figure 2 Personal health services expenditures in 1960, 1990, and 2002. Data from Health Care Financing Review, Medicare and Medicaid Statistical Supplement (2003), Table 4.

have evolved. Whether because of intravascular or endoscopic procedures, many surgical operations can now be done simpler and faster, often as outpatient procedures. At the same time, advances in pharmacy have created medications that have displaced hospital care in many situations.

As a result of these changes, the patterns of health-care expenditures have changed. **Figure 2** traces personal health-care expenditures in the United States from 1960 to 2002. Nursing home and home expenditures grew substantially after the passage of Medicaid in 1964. Between 1990 and 2002 hospital care receded and pharmacy advanced. In the United States, the latter shift created special problems because outpatient drugs had not been included in Medicare coverage. Thus, older people were left in an awkward situation: their basic care was covered, but the means of implementing it was not. The cost of medications was a growing concern. The passage of the Medicare Modernization Act of 2004 was designed to provide drug coverage, but its design left many problems.

While access to medications is a central aspect of assuring adequate care for older persons, misuse of medications poses a major problem as well. The rate of inappropriate prescribing varies from country to country, but it is still substantial. One European study estimated that almost 20% of elderly home-care patients were receiving at least one inappropriate medication.

Hospital Use Concerns

Hospitals are generally dangerous places for older persons. Frail older persons are at high risk for iatrogenic events. From that perspective, efforts to reduce hospital stays or to prevent them altogether can be viewed as positive events. On the other hand, denying older persons adequate hospital care may reflect discrimination. Efforts to control the use of hospitals by older persons began in the United States in 1984 with the imposition of a new approach to paying for hospital care, diagnosis-related groups (DRGs). These DRGs were based on the median lengths of stay (LOS) experienced by older persons. These LOS estimates were tied to costs for a set of over 400 DRGs, clusters of diagnoses that shared LOS characteristics, and made some clinical sense. Moving to this sort of prospective payment system completely changed the incentives for hospitals and thus their behavior. Whereas in the past more care had been a source of revenue, it now became an unreimbursed cost once the hospitals were paid a fixed amount per admission. The hospitals' immediate response was to take active steps to shorten stays and reduce the intensity of care. Concerns about 'quicker and sicker' discharges soon surfaced, but an early evaluation suggested that there was little adverse effect on quality of care.

There was, however, a tremendous impact on the use of posthospital care. Services that had been included as benefits under Medicare but had lain virtually dormant now experienced great growth as those discharged from hospital continued to need support in their recuperation. There was a growth in Medicare-covered home health care, nursing home care, and inpatient rehabilitation. This so-called post-acute care (PAC) became an increasingly large part of the Medicare budget. Indeed, it was soon the fastest growing component.

Much of PAC proved to be interchangeable. Depending on supply and practice styles, care for similar individuals could be provided in various settings. However, some settings were more effective than others. In general, patients discharged to nursing homes experienced the poorest outcomes.

The growth in PAC expenditures led to a demand for imposing cost controls using an approach based on that applied to hospitals. Prospective payment systems were created for each of the three major PAC modalities. Each one was independent, re-enforcing the silo approach that had ignored their potential

interchangeability. The prospective payment for nursing homes was based on a daily rate adjusted for case mix. The payments for home health care and rehabilitation were based on per episode costs estimated on the basis of client characteristics using two separate approaches.

The potential for bundling the costs of PAC into a single payment has been discussed but has not been adopted. Such a bundling approach makes sense on several levels. In addition to the observation about interchangeability, many patients actually experience several types of PAC during the course of their post-hospital care. Separate accounting makes it hard to affix responsibility for outcomes or to develop meaningful accountability.

Integrating Medical and Social Care

In many countries, medical and social (or long-term) care are the responsibilities of different programs. Integrating these two elements of care can be a challenge, but some models suggest at least some success. While the coverage of medical care may be universally available, coverage of social care is often treated as part of the welfare system. In the United States this distinction is reflected in coverage under two separate programs. Medicare is a universal health insurance program for older persons, whereas Medicaid is a welfare program available to poor persons at all ages.

Inevitably, some persons are covered by both programs, but the coordination across the programs is poor. These so-called dual eligibles account for a disproportionate share of resources from both programs. Approximately 17% of individuals enrolled in Medicare were also covered by the Medicaid program; they represented 28% of total Medicare expenditures during 1997. Dual eligibles represent approximately 19% of the Medicaid population, and account for 35% of Medicaid expenditures.

Efforts to address the needs of this subgroup have generally relied on some form of managed care as the means to pool funds from both Medicare and Medicaid. In theory, pooling these funds and developing specifically targeted approaches to meeting the needs of these high-risk frail older persons should improve outcomes. Perhaps the best-known program in this context is the Program of All-Inclusive Care of the Elderly (PACE), which targets a specific subset: dually eligible persons who are deemed eligible for nursing home care by virtue of their disability levels but who continue to live in the community. To enroll in PACE, patients must be willing to accept a PACE physician as their medical care provider. In effect, they must be willing to give up their prior medical care. The key to PACE is coordinated care. All of the staff, from van drivers to physicians, are viewed as members of the caregiving team. Medical care in the PACE model closely follows geriatric principles. Active primary care, with an emphasis on comprehensive assessment, addressing both functional as well as medical concerns, is a hallmark. The active effort to avoid institutional use often requires innovative solutions to providing care. In addition to using formal approaches, such as day care and home care, new venues of service have been created. For example, special housing arrangements have been developed whereby patients can be monitored during clinical exacerbations, using PACE personnel or informal caregivers.

PACE also places demands on the informal caregivers. PACE does not attempt to supplant informal care. Rather, such care is central to its mission of avoiding institutionalization. Whenever such care is available, informal caregivers are expected to provide active support. This is usually achieved by some form of social contracting.

The requirements to change physicians and to attend day care have restricted enrollment. Many frail older persons are reluctant to change their physicians if they have had any sustained relationship.

Unfortunately, the evaluation of the PACE program during its demonstration phase was inadequate. Despite the absence of substantial data to document whether PACE has achieved its promise, it appears that PACE did achieve its goal of reducing the use of institutions. Hospital days and hospital admissions for PACE clients were lower than those for fee-for-service Medicare beneficiaries in general for the first 18 months of the evaluation, an impressive statistic considering the frailty of PACE clients. Likewise, PACE clients had fewer nursing nights and admissions through the first year of the evaluation, but the difference dwindled over time. Perhaps commensurately, PACE clients had more ambulatory visits throughout the 24 months of the evaluation. Much less is known about the clinical outcomes of this care. There were few differences between PACE clients and controls in terms of functional status over time. Nor were there many patterns of differences in terms of self-rated health status, quality of life, or satisfaction. Despite the lack of evidence about an overall benefit from PACE care, it has been incorporated into the mainstream of Medicare managed care.

Several PACE programs have begun to experiment with alternative arrangements, more akin to independent practice associations (IPAs). In these situations, private practitioners could contract with the

PACE program to provide necessary primary care medical services. One such program is the Wisconsin Partnership Program (WPP). Unfortunately, easing the restrictions on physician enrollment was associated with poorer control of utilization. One possible contributing factor was the low rate of participation among physicians; each had on average only six WPP clients. Physicians caring for so few people are unlikely to change the practice styles to accommodate the needs of these frail patients.

Another approach to addressing the needs of dual eligibles is the Minnesota Senior Health Options (MSHO). In contrast to PACE, MSHO addresses elders in both the community and nursing homes; the range of disability is thus much larger. The MSHO program has not had a profound effect on the utilization of persons living in the community, nor has there been any substantial benefit in terms of improved functioning.

In contrast, the utilization effect on nursing home residents has been profound. Much of that benefit can be readily attributed to using services from Evercare, a program that was originally developed as a Medicare managed care plan targeted specifically at nursing residents. The Evercare model, which has been emulated by others, makes active use of nurse practitioners, who add to the overall primary care provided to the nursing home residents and who are also effective in communicating with family members. The Evercare model has been shown to dramatically reduce the use of hospitals and emergency rooms. Much of those savings come from shifting the locus of care from the hospital to the nursing home, thereby avoiding transfers, but some benefit also seems to arise from more aggressive primary care.

Another program that has attempted to address the gulf between medical and social care is the Social Health Maintenance Organization (SHMO). SHMOs are basically Medicare-managed care programs that receive a higher payment, which is designed to cover at least a modicum of long-term care. These programs have been viewed as lacking an aggressive stance in geriatrics; an evaluation suggested that they achieved little more than traditional Medicare-managed care plans.

A Canadian approach to integrating care for frail older persons draws from some of the American experience and tries to encourage more active roles for community physicians, while creating incentives to shift the locus of care from hospitals and nursing homes to community care.

The National Health Service (NHS) in the United Kingdom has embarked on a series of reforms designed to improve health care for older persons. In addition to establishing an agenda that addresses selected geriatric issues, the NHS has also created performance incentives for general practitioners to encourage greater adherence to chronic care guidelines. A substantial proportion of their overall payments will come from actively following these guidelines.

See also: Caregiving and Caring; Medicare and Medicaid and Economic Policy of Health Care.

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Hearing

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Glossary

Presbycusis – Hearing impairment associated with aging.

Tinnitus – Ringing in the ears.

Introduction

The general population in the United States is aging, and the fastest growing age group includes individuals over the age of 65 years. Only 4% of the population was over the age of 65 years in 1900, whereas projections state that over 17% of the population will be over the age of 65 in the year 2020. As the population ages, the number of chronic disabilities, including hearing loss, in that population increases. Communication difficulties related to hearing loss may lead to reduced quality of life, depression, and social isolation in older people. Communication lines begin to break down and frustration increases, which compounds the difficulty in communication. Despite these hardships, hearing loss is often an unrecognized affliction. Older individuals themselves may not recognize the onset of the hearing impairment, deny its existence, or accept it as part of growing old. Unrecognized hearing impairments may go untreated; only a fraction of older people with hearing impairments wear hearing aids, use other assistive listening devices, or receive aural rehabilitation.

Background: Prevalence and Origin of Presbycusis

Hearing impairment associated with aging (presbycusis) is present in older individuals of virtually all societies. Hearing loss is variously estimated to be the third or fourth most common complaint among older people. Tinnitus (ringing in the ears) is related to hearing loss and is the ninth most common complaint of older individuals.

Presbycusis includes both a loss of hearing sensitivity (elevated pure tone thresholds) and a reduced ability to understand speech, especially in noisy or acoustically poor environments. The audiogram (diagram of hearing levels by sound frequency) characteristic of presbycusis indicates a bilateral, symmetrical high-frequency hearing loss that worsens with age. Although men typically have poorer hearing than women, there is no evidence of an intrinsic cause for hearing loss to be determined by gender, and the difference in hearing is generally attributed to lifestyle factors. The rate of deterioration of hearing accelerates with age in both men and women, but men generally show deterioration at more than twice the rate of women. Risk factors for hearing impairment include exposure to noise either on the job or in recreational activities, exposure to ototoxic medications, cardiovascular disease, smoking, high blood pressure, alcohol consumption, and disorders of the hearing mechanism. Studies of normal aging attempt to dissociate disorders from aging, but because these risk factors are pervasive in industrial societies, it may be impossible to determine the amount of hearing loss that is determined by age alone.

Auditory Anatomy and Physiology

External and Middle Ears

A diagram of the external, middle, and inner ears is shown in **Figure 1**. The external ear consists of the auricle (pinna) and the external auditory meatus (ear canal). The pinna is made of a cartilage frame covered in skin, which is continuous with the skin of the external ear canal. The outer one-third to one-half of the ear canal is cartilaginous, and its skin covering bears cerumenous glands and hair follicles. The medial part of the ear canal is osseous and is covered with thin skin. The primary functions of the outer ear are to carry sounds to the middle ear, to assist in sound localization, and to protect the middle ear from the elements. The pinna and ear canal serve as resonators to amplify high-frequency sounds by approximately 10–15 dB. The most common changes with aging are dry and thinning skin, degeneration of collagen, prolapsed ear canals, and an increase in hair growth. The cerumen (ear wax) may become hard and dry and adhere to hairs in the ear canal and cause a conductive hearing loss due to the blocked path of sound into the middle ear. The cerumen may also cause tinnitus, pain, or vertigo (dizziness). Cleaning out the ear canal can be difficult in older individuals, as the thinned skin is easily irritated. Otherwise, the aging changes of the external ear only rarely affect hearing.

The middle ear is an air-filled cavity within the temporal bone that is bounded by the tympanic membrane (ear drum) and the oval window. The middle ear contains three small bones (ossicles) – the malleus, incus, and stapes. The tympanic membrane collects the sound from the external ear canal and delivers it to the ossicular chain, which in turn delivers it to the oval window at the entrance to the fluid-filled cochlea. The area ratio of the tympanic membrane to the oval window and the lever action of the ossicular chain amplify sounds approximately 30 dB to overcome the mismatch of impedance during the conversion of airborne sound waves to fluidborne traveling waves in the cochlea. The Eustachian tube connects the middle ear to the nasopharyanx, and serves to aerate and maintain atmospheric pressure within the middle ear. The

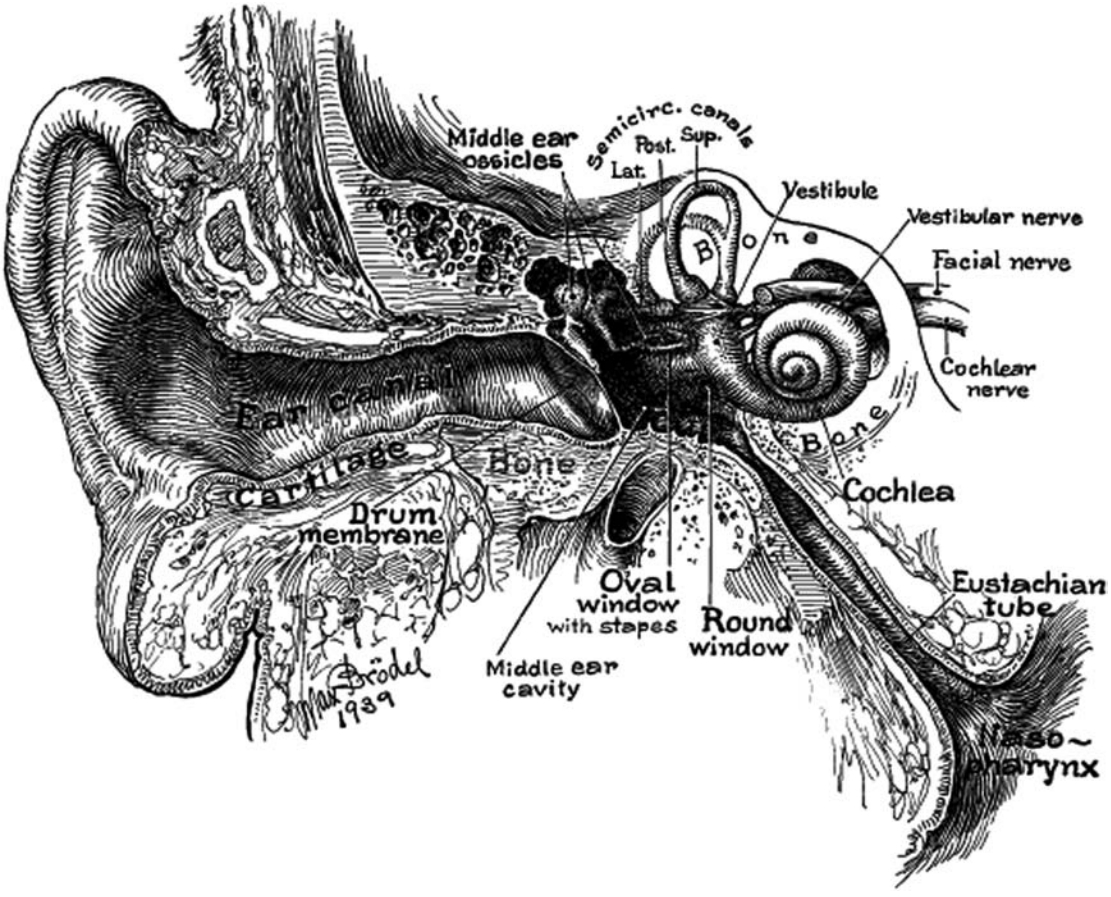

Figure 1 A cross-sectional diagram of the outer, middle, and inner ear, with landmarks labeled. Reprinted with permission from Broedel M (1946) Three unpublished drawings of the anatomy of the human ear. Philadelphia, PA: W. B. Saunders Co.

Eustachian tube is opened by the contraction of three muscles – the tensor veli palatini, levator veli palatini, and salpingopharyngeus. Two muscles, the stapedius and the tensor tympani, contract with loud sounds to reduce low-frequency energy entering the cochlea, thereby protecting it from noise damage.

All of the structures of the middle ear are affected by aging. The tympanic membrane becomes less vascular, thinner, and less elastic. There may be degeneration and arthritic changes in the incudomalleal and incudostapedial joints between the ossicles. The cartilaginous structure of the Eustachian tube may become ossified, and the muscles controlling the opening and closing may atrophy. The fibers of the middle ear muscles degenerate with age. Altogether, these changes may produce little or no effect on functional status of the middle ear and no significant reduction in hearing.

Inner Ear and Auditory Nerve

The inner ear or labyrinth is a bony structure that contains the cochlea of the auditory system for hearing and the vestibule and semicircular canals of the vestibular system for balance. The cochlea is a snail-shaped organ with two and three-quarters turns known as the basal, middle, and apical turns. Within the bony shell is a membranous labyrinth that includes three longitudinal compartments, the scala tympani, scala media, and scala vestibuli. The scalae tympani and vestibuli contain perilymph, a fluid that is high in sodium and similar to cerebral spinal fluid, and the scala media contains endolymph, a fluid high in potassium. The sensory epithelium of the auditory system, the organ of Corti, is situated in the scala media. The organ of Corti, shown in **Figure 2**, consists of the basilar membrane as the floor, supporting cells, tectorial membrane, and two types of hair cells (one row of inner hair cells and three rows of outer hair cells). The lateral wall of the cochlea contains the stria vascularis, which has a rich blood supply and generates the $+80\,\text{mV}$ endocochlear potential that serves as a local source of energy for hair cell function. The footplate of the stapes inserts into the oval window and delivers the mechanical energy to the perilymphatic fluids of the labyrinth. The vibratory motion of the stapes footplate sets up a fluid traveling wave in the cochlea, which propagates down the basilar membrane and stimulates high frequencies at the base and lower frequencies toward

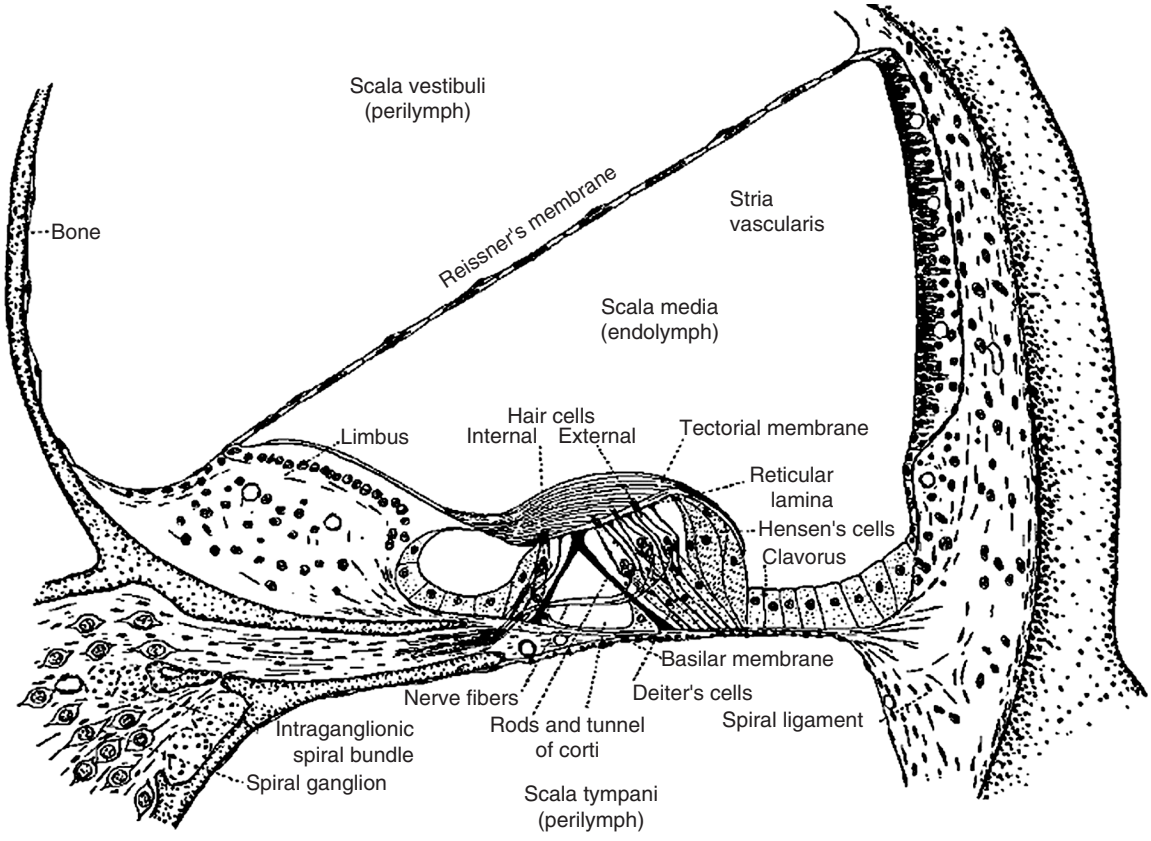

Figure 2 Cross-section diagram through the cochlea showing the organ of Corti. Reprinted with permission from Davis H et al. (1953) Acoustic trauma in the guinea pig. *Journal of the Acoustical Society of America* 25: 1180. Copyright 1953, American Institute of Physics.

the apex. The resultant pressure wave causes mechanical bending of the cilia protruding from the outer hair cells. An active process in the outer hair cells pumps energy into the basilar membrane to sensitize the response of the inner hair cells. The inner hair cells then release neurotransmitters at their base, which diffuse across the synaptic cleft. The chemicals are absorbed by the dendrites of the auditory nerve (cranial nerve VIII) and initiate neural impulses in the fibers of the auditory nerve.

Many age-related changes occur in the cochlea, and in combination they reduce the ability of the cochlea to respond to low-level sounds. Hair cells degenerate, nerve cell bodies in the spiral ganglion degenerate, the endocochlear potential declines, and nerve cells atrophy. Some of these changes result from noise, trauma, and diseases, but some appear to result from the process of aging as well. The basal, or high-frequency, end of the cochlea is the most vulnerable, and the typical result is primarily a high-frequency hearing loss. Primary or secondary loss of neural fibers is thought to result in sensitivity loss and distortion of signal processing, resulting in deficits of speech perception.

Central Auditory Nervous System

The central auditory nervous system (CANS) includes nerve fibers and nuclei (cell bodies) of the brain stem, midbrain, and cortex. The auditory pathways in the brain stem are shown in **Figure 3**. The fiber tracts are both uncrossed and crossed and connect the nuclei on both sides of the brain stem. The function of the CANS is to process signals for recognition of sounds, sound localization, auditory attention, and pattern recognition. With other brain structures, the auditory system controls attention to target sounds in backgrounds of noise and integration of auditory signals

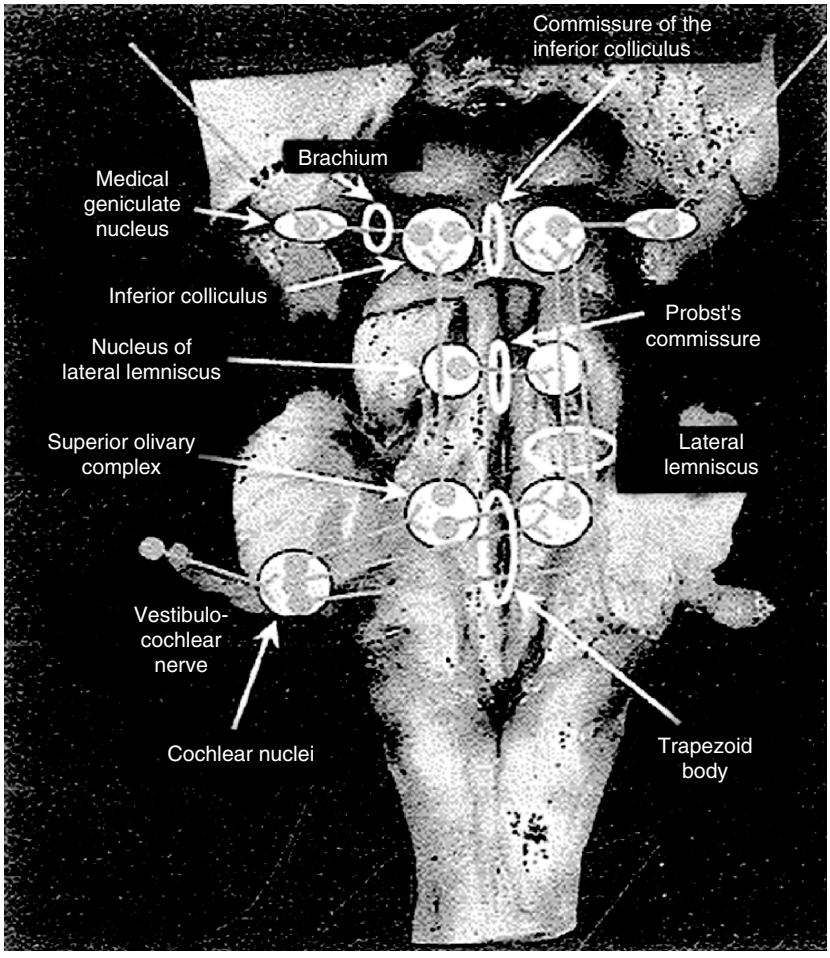

Figure 3 Dorsal view of the brain stem with superimposed schematic organization of subcortical relay stations of the ascending auditory system. Reprinted with permission from Seifritz E et al. (2001) Auditory system: functional magnetic resonance imaging. *Neuroimaging Clinics of North America* 11(2): 276.

with other sensory signals. At the cortical level, recognition and meaning are attached to the sounds.

Aging effects are noted throughout the CANS. Anatomical changes include slower nerve conduction velocity and reduction of synchronous firing due to thinning of axons and loss of myelin. Transmission between neurons may be slowed due to reduced neurotransmitter release and fewer postsynaptic receptors. Efferent feedback may be reduced in efficiency. These CANS changes with aging are more likely to result in central auditory processing deficits as opposed to simple loss of sensitivity and probably contribute to the difficulty older people have in understanding speech in difficult listening environments.

Measures of Auditory Function

Pure Tone Thresholds

Presbycusis presents primarily as poorer hearing for high frequencies compared to low frequencies. A composite audiogram showing auditory thresholds from 730 older individuals is shown in **Figure 4**. On this audiogram, only the thresholds from air-conducted signals are shown. Thresholds are also tested for bone-conducted signals, which bypass the middle ear. A gap between the thresholds from air- and bone-conducted signals would suggest a problem in the outer or middle ears. In older people, the thresholds from air- and bone-conducted signals are typically equal, suggesting that the hearing loss results from a loss of function at the sensory (cochlea) and neural levels of the auditory system.

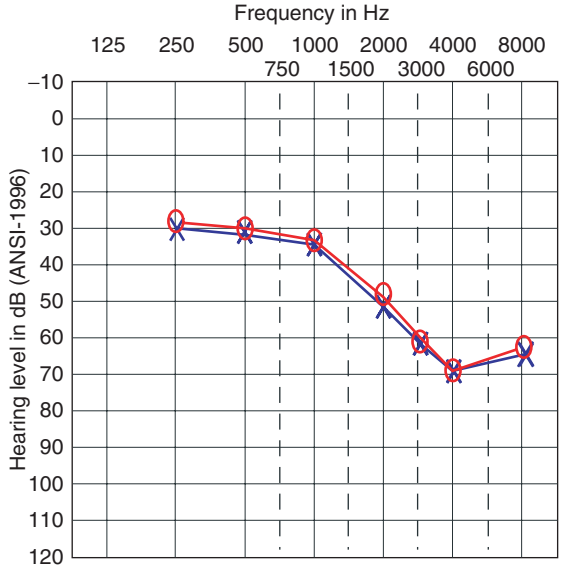

Figure 4 Graph of the average pure-tone thresholds (i.e., audiogram) for the left and right ears of 730 patients 55–88 years of age. Hearing thresholds (ordinate) are represented as a function of test frequency (abscissa). X, left ear; O, right ear. Unpublished data from Richard Wilson, Ph.D.

Audiological evaluations in older adults indicate that hearing loss exists in up to half of the adults over the age of 50 years and up to 90% of the adults over the age of 80 years. Men begin to report a hearing loss in their mid 60s and women report losses about 7 years later. Hearing loss is found four times more often in men than in women, even when risk factors such as education, occupation, and noise exposure are considered. By the age of 70, however, women are just as likely as men to develop hearing loss. After the age of 60, thresholds for pure tone signals decrease at a rate of about 1 dB/year. The rate of decline is initially slower for women than for men, but for many women, the rate of decline accelerates after the age of 70 years.

Presbycusis likely results from a combination of risk factors, including an accumulation of noise exposure from work and leisure activities. Noise exposure has been implicated as a risk factor for hearing loss since studies showed that elders in primitive tribes with minimal noise exposure had significantly less presbycusis than elders in modern industrial societies. In modern societies, individuals who engage in noisy vocational or recreational activities without using ear protection are more likely to suffer from hearing loss than individuals who do not. The hearing loss related to noise exposure interacts with the hearing loss related to aging, such that both appear to share an underlying mechanism. Whereas presbycusis develops with or without noise exposure, aging ears with noise damage initially show accelerated decreases in thresholds compared to aging ears without noise damage, indicating a non-linear addition of hearing loss due to age and noise exposure.

Speech Perception

Older people often complain that they can hear people talking but cannot understand what they are saying. They especially note that understanding speech is difficult in a crowd or a noisy situation where more than one person is talking at the same time. In fact, even if the degree of hearing loss is the same in older and younger individuals, the older persons typically have more difficulty understanding speech in noisy environments.

Speech understanding with aging results from a loss of sensitivity (audibility) as well as a loss of clarity. The hearing loss that most older people have renders inaudible some speech sounds, especially high-frequency consonants that are essential for

distinguishing words. Simply making sounds louder, however, does not completely resolve the problem. The additional loss of clarity in the speech signal may be related to distortion of the message caused by poor auditory processing in the defective cochlea and neural pathways of the auditory system. Because of the combined loss of audibility and clarity, older listeners require speech to be much louder relative to the background noise than younger people do to achieve the same level of understanding.

A variety of speech perception tasks in noise and with degraded speech materials demonstrates the underlying problems of older people. These tasks point to the poor ability of older people to process timing cues in speech and other signals. Older people have difficulty understanding speech that is presented rapidly, compressed, or interrupted with short silent gaps. These difficulties suggest that older people may process speech more slowly than it is presented in some social situations.

Behavioral studies also show auditory perceptual differences between younger and older persons. Older listeners have more difficulty discriminating between continuous and separate events, especially when sounds are soft. Temporal order tasks measure a listener's ability to identify the sequence in which tones are presented. Older adults have difficulty identifying tone sequences that are presented rapidly, again suggesting slowed processing times. General cognitive slowing and a decrease in the speed of perceptual processing may contribute to the poorer temporal processing in older persons.

Cognitive factors clearly can contribute to the speech understanding performance of older persons. When listening to conversations, an individual must be able to switch attention from one talker to another, remember what has been said earlier by one or more speakers, and likely perform both of these tasks in a room with distracting sights and sounds. The cognition required to follow conversations under these circumstances is not trivial. A hearing loss compounds the problem because even a mild hearing loss can be associated with reduced cognition and working (i.e., short-term) memory. Older persons do benefit, however, from contextual cues in the conversation and from a lifetime of experiences. Cognition, therefore, is intricately linked to the ability to understand conversational speech, and any loss in sensory perception is likely to compound the cognitive burden on an older individual.

Auditory Evoked Responses

Otoacoustic emissions (OAEs) are low-level sounds generated by the normal-functioning outer hair cells in the cochlea. The OAEs are generated spontaneously or can be evoked in response to sounds. These sounds are propagated back along the basilar membrane and released into the middle and then external ear, where they are recorded with a sensitive microphone. Two forms of evoked OAEs are recorded clinically: the transient evoked OAEs, which are generated by a click or short tone pip, and the distortion product OAEs, which are generated by an interaction between two pure-tone stimuli close in frequency. If auditory sensitivity is adequately controlled, there appear to be no significant reductions in the amplitudes of either the transient or distortion product OAEs due to age alone.

The auditory brain stem response (ABR) is the neural response to short clicks or tone pips, and is composed of five major waves that are named with Roman numerals. These waves occur within the first 10 ms after stimulus presentation and are recorded via electrodes taped to the scalp. Waves I and II arise from the cranial nerve VIII and the rest are from the auditory brain stem through the level of the lateral lemniscus. The ABRs from older persons typically show longer latencies and smaller amplitudes than the ABRs from younger persons. An example of ABRs of a younger and an older rhesus monkey that demonstrate these changes is shown in **Figure 5**. Specific effects of age are difficult to determine given the interaction between hearing loss and age, both of which may increase the latencies of the waves. Age

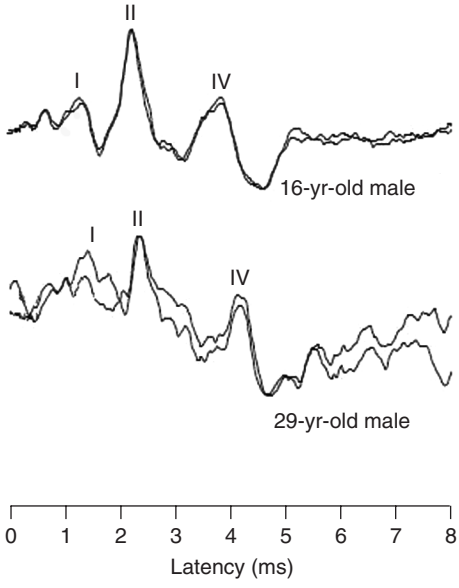

Figure 5 ABR waveforms recorded from a younger rhesus monkey (upper waveform) and an older rhesus monkey (lower waveform), showing the longer latencies and smaller amplitudes of the waveforms in the older monkey.

alone, however, probably contributes less than 0.2 ms to the latency prolongation. Interaction of signals from both ears may be evaluated with the binaural interaction component. The ABR from left ear stimulation is added to the ABR from right ear stimulation, and the binaural response is subtracted from that summation. The binaural interaction component is noted as a difference potential about the latency of wave V. At the brain stem level, the binaural interaction does not appear to be different in younger and older people.

The auditory middle latency responses (AMLRs) appear from 10 to 50 ms after sound stimulation and arise from the upper brain stem and primary auditory cortex. Most studies report that with age, latencies of the peaks Na and Pa are prolonged, and the amplitude of Pa may be enhanced. Although the cause of the enhancement is not certain, some believe that it is related to a reduction of inhibitory input from higher centers. Some hemispheric asymmetries are noted in older individuals when electrodes are placed over the temporal lobes, but these differences have not been correlated with behavioral responses. The binaural interaction component recorded with the AMLR appears to be reduced or absent in some older people.

The auditory long latency responses (ALLRs) include both stimulus-generated and cognitive potentials. These potentials are generated 50–500 ms following presentation of the stimuli. The sources are complex and include the primary auditory cortex, and the electrical activity is spread widely over the scalp. P2, the largest of the stimulus-generated potentials, is significantly smaller in amplitude and longer in latency in older people than in younger people. The amplitude difference between younger and older people for P2 amplitude is greater for activity recorded at the frontal area than at the top of the scalp. This change in the distribution of the electrical activity suggests a change in the underlying generators with age.

The P3 wave is one of many endogenous or cognitive responses that can be recorded using cognitive tasks. Typically a person is asked to note the difference between signals in an oddball paradigm in which a rare signal is randomly interspersed in a sequence of frequent signals. If the listener can distinguish the two signals, a positive response to the rare signals is generated at a latency of approximately 300 ms. The P3 has its shortest latency in early adulthood, and the latency progressively lengthens 1–1.5 ms/year as a person ages into the 90s.

The P3 can be used to demonstrate brain activation that corresponds to behavioral responses. It has been known for quite some time that when words are presented dichotically (different words to both ears simultaneously), a person understands the words presented to the right ear better than words presented to the left ear. This phenomenon is known as the right ear advantage for speech and is attributed to the shorter neural pathway from the right ear across the brain stem to the left hemisphere, the site for speech processing. By contrast, the left ear is at a disadvantage because the neural pathway crosses the brain stem to the right hemisphere and then crosses over the corpus callosum to the left hemisphere for speech processing. The advantage is reversed for non-verbal or tonal signals, which are processed in the right hemisphere and show a left ear advantage. The right ear advantage for speech develops in childhood, reaches a minimum difference in young adulthood, and then appears to increase again with aging.

The P3 can be elicited with both verbal and non-verbal signals and with signals presented dichotically or monotically (each ear separately). Use of these types of signals reveals the distribution of electrical activity in the cortex associated with the right ear advantage for speech and the left ear advantage for non-speech signals. In older adults, in contrast to young adults, the P3 hemispheric activation is asymmetrical for dichotic signals. As shown in **Figure 6A**, for dichotic verbal signals, the right ear produces significantly more P3 hemispheric activation than the left ear, and the opposite situation is seen for dichotic non-verbal signals. As shown in **Figure 6B**, with monotic stimuli, the P3 hemispheric activation is relatively symmetrical when there is no competition for the hemispheric processing centers. This pattern of activation may suggest underlying cortical changes that coincide with the difficulty that many older people have in separating speech from background noise and may lead to predictions regarding which older people will be successful users of binaural hearing aids.

Impact of Presbycusis

Hearing loss can affect all aspects of the life of an older person. The impact of the hearing loss, however, depends on the degree and configuration of the hearing loss, the ability to understand speech, and individual factors, including lifestyle, personality, and general health. A common assessment tool for the impact of the hearing impairment on an individual is the Hearing Handicap Inventory for the Elderly (HHIE) or the screening version, the HHIE-S. These scales consist of questions about the person's perception of the social and emotional impact of the hearing loss in various situations. These scales have only a moderate correlation with actual degree of hearing impairment and underscore the necessity to explore the impact of even mild hearing impairments

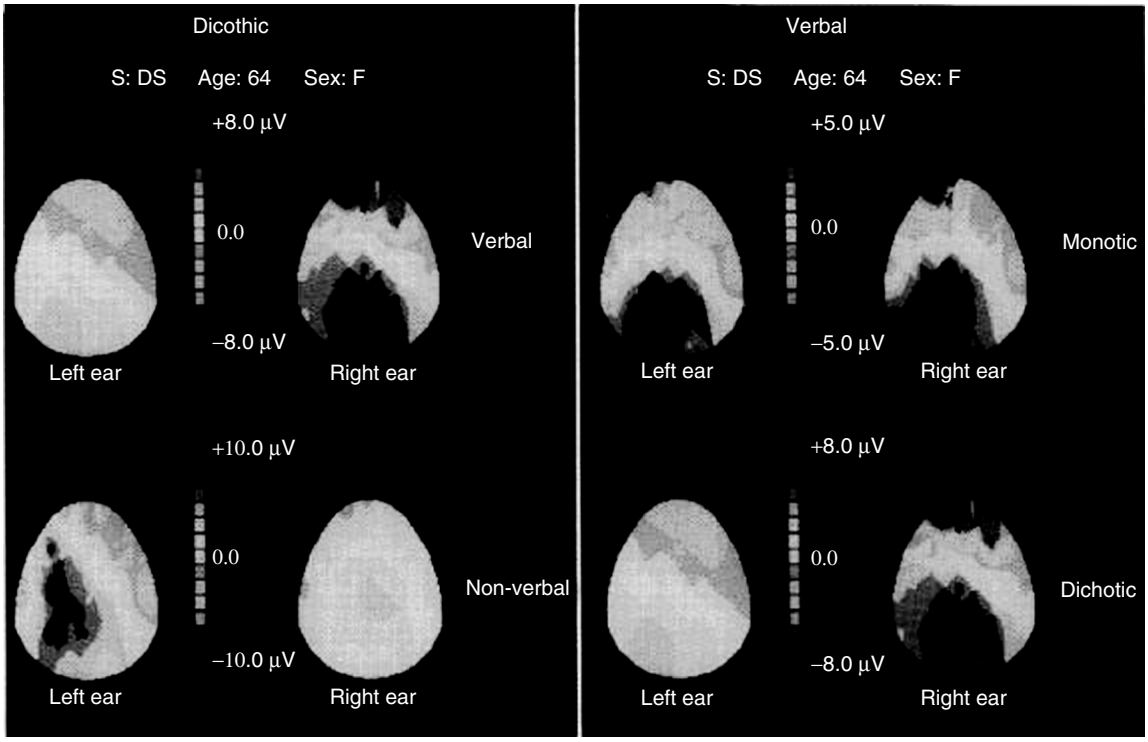

Figure 6 Topographic brain maps of peak P300 waveform in subject DS, a 64-year-old woman with presbycusis who also complained of trouble understanding speech in background noise. Darkest areas reflect greatest positivity. (A) Verbal and non-verbal tasks. (B) Verbal task presented monotically (top) and dichotically (bottom). Reprinted with permission from Jerger J (1997) Functional asymmetries in the auditory system. *The Annals of Otology, Rhinology, and Laryngology* 106(5): 23–30.

on the individual. Because older people may minimize or deny hearing impairment as they do with other chronic disorders, the use of these screening measures may be necessary to reveal an underlying problem that will not be revealed in a quick case history. Only after the problem is evident can a treatment plan be considered.

Older people with hearing impairments may experience depression, anxiety, and social isolation as a result of the difficulty they experience in communication. They may become frustrated, anxious, and less sure of themselves, which causes them to withdraw from their former activities and social contacts. People with hearing impairments are more likely to have other health problems, including high blood pressure, cardiac disease, and poor balance. An association exists between cognitive decline and hearing loss; even a mild hearing loss can result in memory deficits, and the risk of dementia increases with increasing hearing loss. Hospitalized older people in unfamiliar surroundings and without their hearing aids may become disoriented and appear demented.

A significant number of older individuals have vision loss in addition to hearing loss, which compounds the resulting communication handicaps. Estimates of older people experiencing this dual sensory loss range from 6% of community-dwelling elders to 70% of those in assisted living situations. Vision normally supplements hearing by allowing individuals to take advantage of the non-verbal aspects of communication, including speech reading, facial expressions, and gestures. With both hearing and vision impaired, people are less secure in social interactions and experience frustration, fatigue, and embarrassment. Eventually they withdraw from social interactions and activities and experience boredom, loneliness, and inactivity.

Some mitigating factors relate to hearing impairment in older people. Treatment for hearing impairments can significantly reduce the perceived handicap. Women are more likely to seek treatment than men. Older people report less handicap from their hearing loss than younger people with the same degree of hearing loss. Reasons for this difference may include fewer communicative demands placed on older people, less pressure from work, more acceptance of the hearing impairment, and a history of dealing with adversity. Acceptance of the hearing impairment, however, may also prevent older people from seeking treatments and lead to social withdrawal.

Remediation

The best remedy to date for hearing loss is amplification. Hearing aids can be programmed to meet the specific audibility needs of each person based on pure-tone thresholds and speech perception measures. Hearing aids available today include those that are completely digital and programmable and thus are superior to devices available only a decade ago. Recent advances in technology have produced microphones that take advantage of the spatial separation of the speech source and the noise source in the environment. In addition, noise reduction algorithms make use of the spectral and temporal differences between the speech signal and the background noise. The directional microphone technology creates a more advantageous listening environment for the individual hearing aid user by reducing background noise and enhancing the speech signal. Despite these improvements, the most significant problem faced by hearing aid users today remains the difficulty of separating speech from background noise. The enhancement of speech understanding in a background of noise and improvement of listening comfort in noise remain at the forefront of hearing aid research.

Despite the improvements in hearing aids and the customized approach to remediation, fewer than 20% of older persons who are candidates for hearing aids actually wear them. Several factors other than hearing loss influence an individual's motivation to wear a hearing aid. These factors include self-perception of communication problems, the number and quality of conversations experienced by the person, the availability of communication partners, physical health, the perception of hearing aid users as being old, cost of the hearing aid, and belief that hearing aids cannot help.

Several factors are important to consider when selecting a hearing aid for the older person. Possible dexterity problems can inhibit the patient from physically manipulating a small device, but specific modifications on the hearing aids can minimize this problem. Certain cognitive limitations may require more sophisticated devices since hearing aids can be programmed to switch automatically to optimize speech in a quiet environment, a noisy environment, or over the telephone. Finally, the single most important factor in successful hearing aid use is the motivation of the patient.

An individual's perception of his or her hearing problem is an important factor for success in remediation with hearing aids. Older people in general, and older men in particular, report their own hearing loss as less problematic than their communication partner does. Whereas this discrepancy may relate to the stoicism of older individuals who have faced many challenges in their lives, it also reveals the frustration and stress of the partner who tries to communicate with that individual. An individual who minimizes the hearing loss may be more resistant to treatment. Counseling the individual with the hearing impairment and the communication partner is essential to assure a successful hearing aid fitting. Both must understand the advantages and limitations of the hearing aid and must use additional strategies to enhance the communication between them.

For those who cannot wear hearing aids or require supplemental assistance in addition to hearing aids, a variety of assistive listening devices are available to help with communication in general or in specific situations. FM systems, which require the speaker to use a microphone that transmits to a receiver in the ear of the listener, raise the level of the message above the background noise for that listener. These devices are often available in public spaces such as theaters, lectures, and places of worship. Individual ear phones can be attached to the television to allow amplified sound to reach an individual without disturbing other members of the household. Telecommunication devices for the deaf (TDD) can be used for visual transmission of messages. Flashing devices can be attached to the doorbell, telephone, or alarm clock to provide a visual signal to replace or supplement the auditory signal. Pocket talkers are convenient for individuals who are cognitively impaired or otherwise unable to handle hearing aids and rely on others to maintain and manage their amplification devices. Assistive listening devices are relatively inexpensive and are appropriate for those who are unable to afford expensive hearing aids.

Prevention of Presbycusis

Prevention of presbycusis primarily deals with reduction of risk factors for hearing loss. Some sources opine that hearing impairments that accompany aging are due equally to environment and genetics, including interactions of the two. Environmental impact on the development of presbycusis has been studied for over 50 years. Studies beginning in the 1960s noted that members of primitive tribes who live in relatively noise-free environments do develop presbycusis, but the degree of hearing loss is significantly less than that seen in individuals living in modern industrial societies. Public awareness of the damaging effect of noise and its role in the development of hearing loss can help reduce the contribution of noise damage to the development of presbycusis. Noise levels are monitored in many workplaces, and

ear protection may be required for people in work environments that exceed damage risk criteria. Wearing ear protection is urged for people who engage in noisy recreation, including hunting and rock concerts. Noise damage to the hearing mechanism accumulates throughout life and interacts with other causes of hearing impairment to produce serious impairments that increase with aging. Protective measures may reduce the amount of hearing impairment due to this ubiquitous factor in the aging population.

A number of individual risk factors for hearing loss also exist, and some are amenable to control by the individual. Health factors such as hypertension, hyperlipidemia, cardiovascular disease, diabetes, and otologic disease can contribute to hearing loss. Smoking and excessive alcohol consumption have been implicated in hearing loss. These issues suggest that maintaining good general health can minimize hearing loss. Diets deficient in magnesium, vitamin B_{12}, and folate have been noted in hearing impairments in some elderly people, suggesting that some vitamin and mineral supplements may protect against the development of presbycusis. A diet rich in antioxidants has been demonstrated to mitigate the development of presbycusis in some laboratory animals. Calorie-restricted diets, which cut caloric intake but maintain nutrients, increase longevity in many animal models. In many of these animals, the calorie-restricted diet may reduce or postpone the development of presbycusis, but there is no evidence to date that this approach will apply to humans. The fact that all animals, or even all strains of a given animal, do not benefit from these dietary manipulations suggests a role for genes.

The field of genetics is expanding rapidly and includes the identification and understanding of genes that contribute to hearing impairments. An estimated 10% of all genes contribute to the structure and function of the hearing mechanism, and a mutation of a single gene can result in a hearing impairment. Although no specific genes that cause presbycusis have been identified yet, the genes causing nonsyndromic hearing loss have been implicated as likely candidates. Because genes affect mechanisms throughout the body, genetic mutations may produce multiple disorders in addition to the hearing impairment, such as kidney disease, diabetes, and dermatological disorders. Gene expression occurs into adult life, suggesting a continuing role for genes in hearing function. Mutations in mitochondrial genes have been associated with hearing impairments and may lead to disorders in adulthood because numerous cell divisions are required for cells to accumulate enough mutations to cause symptoms. Some genetic mutations interact with environmental factors, such as noise and ototoxic medications, to increase the likelihood of hearing impairment.

See also: Human Factors Engineering and Ergonomics; Language and Communication in Aging; Speech and Communication (speech styles); Vision.

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Hematology and Aging

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Glossary

Anemia – Lower than normal range of haemoglobin concentration: 13 g/dl for men and 12 g/dl for women.

Erythrocytes – Red blood cells.

Hematology – The study of blood and the disorders that affect blood.

Leukemia – A malignant transformation of white blood cell precursors and an accumulation of these transformed cells.

Leukocytes – White blood cells that are critical element sin the body's protection against infection and tumors.

Serum – Plasma that is devoid of coagulation factors.

Thrombocytes (also called platelets) – Cellular fragments of bone marrow megakaryocytes that are central to the control of bleeding.

Introduction

Hematology is the study of blood and the disorders that affect blood. Blood is composed of cellular elements and plasma, which itself is composed of proteins, fats, hormones, and other organic and inorganic chemicals. Plasma devoid of coagulation factors is termed serum.

Most circulating cells are derived from a single hematopoietic stem cell. The life span of blood cells is genetically predetermined. Therefore, hematopoiesis is a lifelong continuous process. Stem cells lack the surface molecules, which are associated with differentiation (maturation), but they do express the CD34 molecule on their surface, a feature that has proven to have important clinical implications. Hematopoietic stem cells give rise to unipotent progenitor cells, which then divide and differentiate into cells of a specific lineage. This differentiation process is considered to be random. Once a specific cell line is determined (e.g., leukocyte, erythrocyte), the progenitor cells go through further differentiation to manifest their ultimate predestined phenotype. This is accomplished by up-regulation of specific receptors under the influence of multiple cytokines and growth factors. Some of these cytokines, for example, erythropoietin and granulocyte-colony stimulating factor, have, in recent years, become important clinical tools.

With aging there is a notable reduction in the capacity to produce new blood cells. Yet, unless there is substantial physiological stress, the number of circulating cells remains fairly constant. Quantitative deficiencies are only apparent when stress produces a demand that exceeds reserve proliferative capacity. Such a demand might occur during an acute infection or after cytotoxic chemotherapy. Significant qualitative deficiencies in blood cell function are not thought to be a consequence of aging, but may be associated with age-associated chronic diseases.

The three major types of blood cells are erythrocytes, leukocytes, and platelets. Deficiency or overproduction of each of these cell types can lead to major clinical consequences.

Erythrocytes

The major role of erythrocytes or red blood cells is to transport oxygen. This is accomplished by a complex interaction of oxygen with the primary erythrocyte protein, hemoglobin. The average life span of red cells is 120 days. Therefore, to maintain steady state, approximately 0.8 to 1% of the total circulating red blood cells need to be replaced each day. If they are not, the red cell volume will decline and a condition termed anemia will develop.

Anemia

The lower limit of the normal range for hemoglobin concentration in blood, established by the World Health Organization, is 13 g/dl for men and 12 g/dl for women. Anemia occurs when there is a persistent decline in the hemoglobin concentration from the normal range accepted for a particular group. Hemoglobin levels tend to be lower in women and in certain racial groups, but the reasons for this are not fully understood.

Anemia is the most frequently encountered hematologic problem in the elderly. Hemoglobin concentration begins to show a steady decline in the sixth decade and beyond. It remains controversial whether aging results in anemia, but the current prevalent opinion is that the age-associated increase is the

result of coexisting disease or nutritional deficiencies and is not a consequence of aging itself.

Anemia may be characterized in a number of ways. One useful approach is classification on the basis of erythrocyte size. Accordingly, there are three major categories: microcytic, normocytic, and macrocytic anemia.

Microcytic Anemia Microcytic anemias are characterized by red blood cells with a mean corpuscular volume of less than 80 fl. The major causes of microcytic anemia in adults are iron deficiency, inflammatory disease, and thalassemia.

The most common cause of microcytic anemia is iron deficiency. This can occur due to inadequate nutritional intake, which is commonly observed in older people due to a change in dietary habits, dental problems, or malabsorption. However, the major cause of iron deficiency is blood loss, primarily through the gastrointestinal (GI) tract. It is very important to survey the GI tract in any case of otherwise unexplained iron deficiency, as iron deficiency anemia is one of the most common presentations of GI malignancy. Uterine or vaginal bleeding can also be the result of a developing cancer and a gynecological exam is warranted in women who present with iron deficiency.

Iron deficiency anemia is usually detected during routine laboratory testing. Although the serum ferritin is considered to be the most useful test in the diagnosis, it can sometimes be misleading, as this protein is also an acute phase reactant and can be elevated in inflammatory states. The measurement of the soluble transferrin receptor appears to be a more sensitive test, but it has yet to gain widespread clinical use.

Once iron deficiency is identified and a cause established, the most effective therapy is reversal of the identified cause (e.g., removal of colonic polyp) and the administration of iron supplementation. Usually, this can be accomplished with oral iron preparations. The treatment phase usually takes about 6 months. Oral iron is often not well tolerated, particularly by older patients, primarily because it is associated with constipation. Thus, lack of compliance with treatment recommendations becomes an issue and should be considered if the laboratory indicators do not reflect improvement within 2 months. Absorption may be erratic and, as mentioned, oral preparations may be intolerable for some patients. For these, parenteral preparations are now available, and many physicians are currently prepared to administer these either in their office or at an infusion clinic.

Other causes of microcytic anemia include thalassemia and inflammation. Many chronic diseases are associated with microcytic anemia (e.g., cancer, arthritis, infection, and even atherosclerosis and diabetes). Although some patients will also have iron deficiency, most will have laboratory evidence for adequate total body iron stores. Typically, such patients will have microcytic anemia, a clinically apparent inflammatory or chronic disease, and an elevated erythrocyte sedimentation rate (ESR). The mechanism of inflammation-associated anemia is not completely understood, but likely involves proinflammatory cytokines such as interleukin-6 and the newly described liver peptide hepcidin.

Normocytic Anemia Normocytic anemias are characterized by red blood cells that have mean corpuscular volumes of 80 to 100 fl.

Acute blood loss is the most common cause of normocytic anemia. In the absence of acute blood loss, other causes include hemolysis; early nutritional deficiency of iron, vitamin B_{12}, or folic acid; or erythropoietin deficiency secondary to kidney impairment.

Hemolytic anemia can be further defined as either intravascular (red blood cell destruction within blood vessels) or extravascular (red blood cell destruction within the spleen or liver). These conditions can be acute, subacute, or chronic and are diagnosed by laboratory tests, e.g., elevated levels of lactate dehydrogenase (LDH), indirect bilirubin, carbon monoxide, and urinary urobilinogen. The reticulocyte count is usually elevated, as the body attempts to compensate for the acute blood loss. Examination of the peripheral blood smear is crucial to help determine the cause of hemolysis. Often, the cause is secondary to an antibody, which either specifically or non-specifically binds to the red blood cell surface, causing direct (intravascular) or indirect (extravascular) hemolysis. The cause of such antibodies is sometimes associated with drugs (e.g., penicillin) or infection (e.g., *Mycoplasma pneumoniae*). Drugs may also result in hemolytic anemia directly, without producing antibodies. An offending drug or infectious agent is frequently not uncovered in a condition termed autoimmune hemolytic anemia. Treatment is geared toward stabilization of the underlying disease process, and transfusions are potentially dangerous because of the potential for exaggerating the hemolytic process.

Macrocytic Anemia Macrocytic anemias are characterized by red blood cells that have mean corpuscular volumes of greater than 100 fl. The three most common causes of macrocytic anemia are substance abuse, drug toxicity, and nutritional deficiency.

Substance abuse Both alcohol and tobacco abuse can lead to a macrocytic anemia.

Drug toxicity Drugs that commonly lead to macrocytic anemia are hydroxyurea, methotrexate, trimethoprim, and most cytotoxic chemotherapeutic agents.

Nutritional deficiency Vitamin B_{12} and folic acid deficiency are the two most common nutritional causes of macrocytosis. Folate deficiency is usually manifest by decreased folate levels in the serum or red blood cells. However, the most practical way to assess for folic acid deficiency is to measure serum homocysteine levels. Folic acid is required to convert homocysteine to methionine, and when it is deficient, homocysteine levels rise. High homocysteine levels can lead to more serious cardiovascular consequences.

B_{12} deficiency is typically discovered by low serum B_{12} levels. In the elderly, however, serum levels may be inaccurate. Measurement of the serum methylmalonic acid is a more accurate way to assess for B_{12} deficiency. B_{12} is a required cofactor in the conversion of methylmalonyl coenzyme A to succinyl coenzyme A. Therefore, in true B_{12}-deficient states, the levels of methylmalonyl coenzyme A would be expected to rise.

B_{12} deficiency can result from an inadequate nutritional intake of vitamin B_{12} or an inability to absorb vitamin B_{12} from the GI tract. This is often caused by atrophic gastritis or the unavailability of the intrinsic factor that is required to absorb B_{12} from the gut, resulting in pernicious anemia.

B_{12} deficiency can have a profound effect on DNA synthesis throughout the body, particularly in the central nervous system. In severe cases, permanent motor neuron injury and dementia (megaloblastic madness) can result. Thus, a comprehensive effort to establish the cause and implement correction of B_{12} deficiency is warranted in any patient with macrocytic anemia.

Other causes of macrocytosis can be liver disease and hypothyroidism.

Hemoglobinopathies

Hemoglobinopathies represent the most common genetic disorder in humans. Sickle cell anemia and thalassemia are genetic disorders that result in abnormal hemoglobin synthesis. It has been postulated that there is an evolutionary advantage in preserving these genetic mutations in certain regions of the world, as their presence has provided protection against malarial death.

Polycythemia Vera (PV)

Erythrocytosis (or polycythemia) is an increase in the hemoglobin concentration of the blood. This can result from an increase in the number of red blood cells or a decrease in the plasma volume that gives the appearance of a relative increase in red cells. Thus, polycythemia can occur as a result of reduced plasma volume (dehydration) or as a consequence of cigarette smoking, other lung disease, or living at high altitudes. In these situations, the red cell mass has been expanded by a compensatory mechanism to overcome chronic hypoxia. In contrast, polycythemia vera (PV) is a specific myeloproliferative disorder in which the red cell mass is expanded inappropriately. This disease occurs with a greater frequency in people over the age of 60 years, and there is a slight increase in prevalence in men versus women. Clinical manifestations result from whole blood hyperviscosity and associated decrease in oxygen delivery to tissues. Clinical signs and symptoms include headaches, dizziness, dyspnea, blurred vision, facial plethora, and paresthesias. Splenomegaly is common; this produces abdominal discomfort, weight loss, and night sweats. For unknown reasons, pruritus is common.

The diagnosis is suspected when there is an increased red cell mass (hemoglobin greater than 20 g/dl) with low serum erythropoietin levels in the absence of secondary causes. The diagnosis can be confirmed by determination of red cell mass by isotope dilution and cytogenetic studies. This is a chronic disease with a median survival of 15 years at time of diagnosis. People with this diagnosis need to be monitored closely for cardiovascular complications arising from whole blood hyperviscosity and also for progression to acute leukemia or myelofibrosis. Treatment involves routine phlebotomy. Hydroxyurea should be considered for patients over 70 years old and those with a history of thrombosis or thrombocytosis.

Leukocytes

Leukocytes or white blood cells are critical elements in the body's protection against infection and tumors. There are three major types of leukocytes: monocytes, lymphocytes, and granulocytes, the latter of which are further classified by staining characteristics as neutrophils, basophils, or eosinophils.

Neutropenia

Neutropenia, or low neutrophil count, can be genetic or acquired. Adults presenting with new-onset neutropenia most often have an acquired neutropenia due to reduced production, peripheral destruction, or

improper storage leading to a reduced number of these cells in the peripheral circulation.

The most common cause of neutropenia is reduced production secondary to drug toxicity. Although neutropenia will most often develop within a few weeks of initial exposure to the offending drug, it can potentially develop at any time, even after prolonged exposure to a particular medication. Older persons are particularly at risk for developing drug-induced neutropenia. The most common offending agents are cancer chemotherapeutic drugs and antibiotics, especially of the penicillin, cephalosporin, and sulfa classes. Other medications that have been known to cause neutropenia are thyroid-suppressing agents, anti-arrhythmic drugs, and non-steroidal anti-inflammatory agents. Any drug can potentially cause this problem and should be suspected when temporally related to the development of neutropenia.

Infections, especially viral infections, are also a major cause of neutropenia. If this is suspected as the cause and the patient is otherwise stable, the blood counts should be repeated to ensure that the white blood cell count is within the normal range. Bacterial infection, particularly when overwhelming (sepsis), is associated with a drop in white count, a finding with negative prognostic implications.

Cyclic Neutropenia Cyclic neutropenia is a genetic disorder that is often not diagnosed until adulthood. It is characterized by low white blood cell count associated with episodes of malaise, fatigue, oral ulcers, and cervical lymph node enlargement lasting 3 to 4 days occurring every 3 to 4 weeks. If this diagnosis is suspected, the white blood cell count should be checked regularly (two times a week for 2 months) to establish a consistent pattern.

Benign Familial Neutropenia Benign familial neutropenia is a condition that involves a slightly decreased white blood cell count without any other clinical evidence of disease. The bone marrow exam reveals normal cellularity with normal red blood cell and platelet counts. This finding is more common within certain ethnic groups, including African Americans, West Indians, and Yemenite Jews.

No treatment is required, and standard of care involves routine surveillance of the white blood cell count.

Leukemia

Leukemia results from a malignant transformation of white blood cell precursors and an accumulation of these transformed cells. Leukemias can be divided into acute or chronic based on the maturation level of the cells that are affected.

Acute Leukemia Acute leukemia results from a malignant transformation of white blood cells occurring in immature hematopoietic cells that progresses rapidly to death if untreated. A combination of genetic and environmental factors has been implicated in the development of acute leukemia. There is an increased incidence in individuals of Eastern European Jewish descent, in people with first-degree relatives with leukemia, particularly identical twins, and also in those with other genetic disorders such as Down's syndrome, Fanconi's anemia, Bloom syndrome, and ataxia telangiectasia. Environmental factors include ionizing radiation from an atomic bomb or nuclear plant accidents, benzene petroleum products, and antineoplastic agents, especially alkylating agents.

Acute leukemia was initially classified into myelocytic and lymphocytic subtypes. In the 1970s, a group of French, American, and British pathologists devised the FAB system of classification, which has become the universally accepted system of classifying acute leukemias. This system incorporates morphology, cytochemistry, cytogenetics, and immunophenotype.

Acute lymphocytic leukemia (ALL) Based on the FAB system, acute lymphocytic leukemia (ALL) can be subclassified into four subtypes: early pre-B, pre-B, B cell, and T cell. Although ALL can occur at any age, ALL is most commonly diagnosed in young children.

Children are reported to have very high cure rates, from 70 to 90%, with aggressive chemotherapy. Older people, unfortunately, do not fare as well. The recurrence-free rate 5 years after treatment is reported to be 35 to 40%.

Treatment involves aggressive chemotherapy that is often quite toxic in the elderly. Yet older patients (over the age of 65 years) have treatment responses similar to younger adults (unlike the situation for acute myelogenous leukemia, as noted below). The use of autologous bone marrow or stem cell transplant is being explored for the treatment of older patients, but the results to date are inconclusive.

Acute myelogenous leukemia (AML) In contrast to ALL, most cases of acute myelogenous leukemia (AML) occur in adults, and the frequency increases with advancing age. The FAB classification system breaks this type of leukemia into seven subtypes of AML (M1 to M7). The median age at diagnosis is 60 years.

Remission rates for adults with AML are higher than those with ALL, but long-term survival is comparable. Approximately 65% of those treated respond to initial induction therapy that typically consists of a combination of cytosine arabinoside and

an anthracycline. Allogeneic or autologous bone marrow transplant can be considered for patients in first or second remission, although the value of such an approach has yet to be established for those over the age of 60 years.

It has been said that older patients (over the age of 70 years) with many forms of cancer (e.g., breast cancer) have more indolent tumor growth and spread. Investigations have led to several features of senescent tissues that may account for this. However, the experience with AML is in stark contrast. Older patients with this disorder are less likely to achieve a complete remission, and survival is considerably shorter for the oldest patients with this disease.

Chronic Leukemia In contrast to acute leukemia, chronic leukemia results from a malignant transformation of mature leukocytes, and this disease usually has a more indolent course.

Chronic lymphocytic leukemia (CLL) Chronic lymphocytic leukemia (CLL) makes up more than 90% of the chronic lymphoid leukemias and is the most prevalent form of leukemia in the Western world. It mostly occurs in adults and is very rare in children. The prevalence is greater in men and in Caucasians. The classification system used for this leukemia is the Rai system, which is a clinical staging system based on absolute lymphocyte count and presence of lymphadenopathy, splenomegaly, anemia, and thrombocytopenia.

Typically, CLL is an indolent disease. Adults with low-stage disease with white blood counts less than 30 000/UL do not have any change in life expectancy when compared to age-matched controls without CLL. However, those with more advanced stage disease do not fare as well. Treatment is indicated for only those with symptomatic disease at any stage. Several chemotherapeutic agents are effective against CLL, but fludarabine is currently considered first-line therapy. As with acute leukemia, autologous bone marrow and peripheral blood stem cell transplantation are currently being explored.

Chronic myelogenous leukemia (CML) Chronic myelogenous leukemia (CML) results from a clonal expansion of a hematopoietic stem cell. The disease is characterized by a cytogenetic abnormality (Philadelphia chromosome) that heralds a reciprocal translocation between chromosomes 9 and 22. This change approximates a cellular oncogene (abl) from chromosome 9 close to the bcr gene of chromosome 22, resulting in the fusion gene (bcr/abl) that is oncogenic. CML occurs early in life but increases in incidence, occurring most commonly in the sixth and seventh decades.

Most patients are asymptomatic at presentation, with diagnosis typically made by routine blood analysis. The chronic phase is indolent for several years but may be associated with fatigue, weight loss, splenomegaly, and thrombocytosis. Untreated, the disease progresses from the initial chronic phase to blast crisis with an intermediate accelerated phase. Although interferon, hydroxyurea, and busulfan are all active, the introduction of imatinib (Gleevec) has dramatically improved the outlook for CML patients. This agent causes inhibition of the bcr-abl tyrosine kinase resulting in suppression of the CML clone. Imatinib is now considered to be first-line therapy, and overall survival, which had been measured in months, is now well over a decade.

Multiple Myeloma

Multiple myeloma results from a malignant proliferation of a single clone of plasma cells. This is a common disorder and represents approximately 10% of the hematologic malignancies in Western countries. The median age of diagnosis is 65 years, and the incidence is slightly higher in males and in those of African descent.

Clinical manifestations include bone pain, weakness, and fatigue. Initial laboratory findings may be non-specific but include anemia, hypercalcemia, hyperproteinemia, proteinuria, and renal insufficiency. Because of the non-specific nature of the presenting symptoms (bone pain, fatigue), delays in diagnosis are typically 6 months or more. If the diagnosis is suspected based on the clinical presentation and initial laboratory data, a serum protein electrophoresis should be done, which will show a localized band in approximately 80% of people with the disease. The diagnosis can be confirmed by a bone marrow biopsy.

Monoclonal protein may present in serum without myeloma or malignant disease. Thus, the presence of an abnormal protein electrophoresis should be considered in the context of the patient and the presence or absence of bone or kidney disease, hypercalcemia, or anemia. Bone marrow aspiration may reveal unusual-appearing plasma cells typical of myeloma, but not always. The presence of benign monoclonal proteins (paraproteinemia) increases with each advancing decade. Thus, the presence of a monoclonal protein in the blood of an older patient warrants special attention. Although it is likely to be a benign condition, it can reflect early multiple myeloma. A reasonable approach for a patient without other signs of myeloma (bone or kidney disease) is to

follow the level of paraprotein at regular intervals (e.g., every 3 months). Benign paraproteinemia will remain stable. If early myeloma is present, paraprotein levels will increase.

Thrombocytes

Thrombocytes (platelets) are cellular fragments of bone marrow megakaryocytes. These small elements (approximately 1–3 μm in diameter) are central to the control of bleeding (hemostasis). When the numbers are low (thrombocytopenia) or function is impaired, spontaneous hemorrhage can result. The normal platelet count in peripheral blood ranges from 150×10^6 to 400×10^6/l.

Thrombocytopenia

Low platelet counts can result from decreased bone marrow production, increased splenic sequestration, or intravascular destruction. In general, spontaneous bleeding due to thrombocytopenia is uncommon unless the platelet count falls below 20×10^6/l.

Non-immune-Mediated Thrombocytopenia Platelet destruction can be caused by immune and non-immune-mediated mechanisms. Non-immune-mediated mechanisms include vasculitis, hemolytic uremic syndrome (HUS), thrombotic thrombocytopenic purpura (TTP), and disseminated intravascular coagulation (DIC). HUS and TTP are characterized by small blood vessel red blood cell damage or destruction (microangiopathic hemolytic anemia), thrombocytopenia, neurologic symptoms, fever, and renal insufficiency.

TTP and HUS are medical emergencies requiring prompt hospitalization and the implementation of medical therapy. For TTP, the immediate implementation of plasma exchange (plasmapheresis) can be life saving.

DIC is also a medical emergency and is usually associated with systemic illness, such as sepsis. Treatment involves supportive therapy, with cryoprecipitate for fibrinogen levels below 100 mg/dl, fresh frozen plasma if a deficiency of coagulation factors has resulted in a prolonged prothrombin time (PT), and platelet transfusion if the platelet count falls below 10×10^6/l or even with higher levels if there is evidence of acute bleeding.

Immune-Mediated Thrombocytopenia (ITP) ITP can be acute or chronic and may be the result of an unusual response to common drugs or infections. Alternatively, the disorder may develop without associated drug or infection (idiopathic thrombocytopenia purpura). Of the many drugs that can lead to thrombocytopenia, heparin is the most common cause of drug-induced thrombocytopenia in hospitalized patients.

Treatment of ITP involves removal of the offending agent or appropriate treatment with antibiotics. Additional therapies have included corticosteroids, intravenous gamma globulins, cytotoxic chemotherapy (e.g., cyclophosphamide), androgens, and, most recently, rituximab (a monoclonal antibody to a subset of B lymphocytes). Refractory patients may benefit from splenectomy.

Thrombocytosis

Thrombocytosis or platelet overproduction is most commonly observed with acute or chronic inflammation or iron deficiency. Most typically, patients with reactive thrombocytosis have platelet counts between 400×10^6 and 900×10^6/l; counts over 1000×10^6/l are very uncommon. The treatment for reactive thrombocytosis should focus on the cause.

Thrombocytosis may also be the result of another myeloproliferative disorder, essential thrombocythemia (ET). This disorder is characterized by platelet counts greater than 1000×10^6/l associated with moderate leukocytosis, splenomegaly, and either excessive clotting or bleeding.

Treatment of ET depends upon the overall clinical picture. Those with a history of recent thrombosis, age greater than 60 years, cardiovascular or cerebrovascular disease, or counts in excess of 1000×10^6/l are candidates for treatment with hydroxyurea, interferon, or agrylin. As is the case with other myeloproliferative disorders (chronic myelogenous leukemia, polycythemia vera myelofibrosis, and agnogenic myeloid metaplasia), a percentage of ET patients will have their disease evolve to acute leukemia or to marrow fibrosis. However, the majority of patients under medical management survive without complications for a decade or more.

Disorders of the Clotting System

Disorders of the clotting system can result in excessive bleeding or pathological blood clots.

Bleeding Disorders

Bleeding disorders can be inherited or acquired. They result from an inadequate amount or functional impairment of platelets or clotting factors.

Inherited Bleeding Disorders Inherited bleeding disorders, such as von Williebrand's disease or hemophilia, are infrequently observed in geriatric medicine.

von Willebrand's disease (VWD) The most common inherited bleeding disorder is von Willebrand's disease (VWD); in certain populations, its prevalence can be as high as 1 to 2%. von Willebrand's factor (VWF) is a plasma glycoprotein produced by platelets and vascular endothelial cells. VWF aids in platelet adhesion to other platelets as well as to vascular endothelium. It also serves as a transport protein for factor VIII. VWD is subdivided into three different subtypes based on the quantity and quality of VWF present in the circulation. With the exception of type III disease, all other forms are inherited as autosomal dominant traits. Bleeding time is prolonged in all three types. The PT is usually within normal limits, but the partial thromboplastin time (PTT) may be prolonged if the VWF levels fall low enough to have an impact on the factor VIII levels.

Treatment is indicated for bleeding or as prophylaxis prior to surgery. Treatment options include DDAVP, antifibrinolytic agents, and plasma. DDAVP promotes release of VWF from endothelial cells and increases factor VIII levels. Antifibrinolytic agents include aminocaproic acid and tranexamic acid both of which inhibit clot lysis. In addition, recombinant clotting factor concentrates are under investigation for future use in the treatment of this disease.

Hemophilia Hemophilia is a congenital bleeding disorder that results from a deficiency of clotting factors. Hemophilia A results from a factor VIII deficiency, and B results from a factor IX deficiency. Hemophilia A and B are X linked recessive disorders. Hemophilia C results from a factor XI deficiency that follows an autosomal dominant inheritance pattern.

The clinical manifestations depend on the severity of the disease, and these disorders are rarely seen in geriatric medicine. Patients with mild disease have increased bruising and bleeding after trauma or surgery. Those with more severe forms of the disease can have spontaneous bleeding. The soft tissues and joints are the typical bleeding sites for hemophiliacs, although bleeding can occur anywhere in the body.

Treatment includes DDAVP, antifibrinolytic agents, plasma-derived clotting factor concentrates, and recombinant clotting factor concentrates.

Acquired Bleeding Disorders The acquired bleeding disorders include inhibitors to plasma coagulation factors such as inhibitors to factor VIII. The clinical manifestations and treatment options are similar to those for hemophilia, but this disorder usually occurs in people over 60 years of age and shows an equal distribution between the sexes.

There is also a form of acquired VWD that most often occurs in conjunction with other disease processes such as autoimmune disease, myeloproliferative disorder, lymphoproliferative disease, dysproteinemia, multiple myeloma, and hypothyroidism. Clinical manifestations and treatment are similar to those of the congenital form of the disease.

Thrombotic Disorders

There are many factors that predispose certain individuals to develop blood clots. Thrombosis can occur in the arterial or venous systems. Venous thrombi typically are composed of red cells and large amounts of fibrin. In contrast, arterial clots are composed primarily of platelets with only a small amount of fibrin deposition. The human body employs a variety of mechanisms to prevent spontaneous thrombus formation and subsequent occlusion of blood vessels. Both the vascular endothelium and plasma have naturally occurring anticoagulants that serve to neutralize or inactivate procoagulants. Under steady-state conditions, the anticoagulants prevail and blood remains liquid. However, when exposed to tissue injury, procoagulants predominate and a clot is formed. If there is a congenital (e.g., protein C or protein S) deficiency of anticoagulants or an acquired increase in procoagulant activity (e.g., with certain cancers), the patient may develop a hypercoagulable state characterized by spontaneous deep vein thrombus formation and possibly pulmonary embolus.

Inherited Thrombotic Disorders The most commonly inherited abnormalities include deficiencies of antithrombin III, protein S, or protein C or mutations in factor II (prothrombin) or factor V (factor V Leiden). Any of these abnormalities may lead to increased clot development. People who have a venous thromboembolism in the presence of one of these defects should be considered for long-term anticoagulation therapy.

Acquired Thrombotic Disorders The acquired thrombotic disorders include the antiphospholipid antibody syndromes, including lupus anticoagulant and anticardiolipin antibody. Treatment with chronic anticoagulation therapy is dependent on the clinical history. Those people who do not have a history of venous thromboembolism do not necessarily require chronic anticoagulation therapy.

Hyperhomocysteinemia Hyperhomocysteinemia can be inherited or acquired. Elevated homocysteine levels are thought to inhibit the expression of thrombomodulin from the vascular endothelium.

Elevations of homocysteine can be found with B_6, B_{12}, and folic acid deficiency as well as with renal insuffiency and hypothyroidism. Hyperhomocysteinemia may also result from mutation of the methylene tetrahydrofolate reductase (MTHFR) gene. Treatment should be geared toward the underlying disease process and nutritional support, especially with folic acid supplementation. Patients with a homozygous MTHFR gene mutation who develop deep vein thrombosis should be considered for lifelong anticoagulation.

Bone Marrow Failure

Bone marrow failure results in an inability of the bone marrow to manufacture one or multiple cell lines. Included in this category of hematologic illness is myelodysplasia (common) and aplastic anemia (uncommon).

Myelodysplasia (MDS)

Myelodysplasia (MDS) results from a clonal disorder of the hematopoietic stem cells, which results in cytopenias secondary to ineffective hematopoiesis. This usually occurs in older people, and the median age at diagnosis is approximately 70 years. The incidence is higher in men. MDS has been subdivided into five different categories by the FAB cooperative group based on the presence or absence of ringed sideroblasts, the degree of dysplastic features in the marrow aspirate, and the percentage of myeloblasts.

The clinical presentation often involves refractory anemia, neutropenia, and thrombocytopenia. Patients frequently seek medical attention for chronic infections of the lower respiratory tract and skin abscesses. Diagnosis is made by bone marrow biopsy and cytogenetic studies.

The natural history of the disease ranges from chronic anemia to rapidly progressive acute leukemia. Until recently, treatment has been primarily supportive. MDS patients are often dependent on blood transfusions and may require iron chelation therapy as a result of transfusion-related iron overload. Cytoreductive chemotherapy has been disappointing. However, recently 5′ azacytidine and thalidomide (or thalidomide analog) have been shown to induce meaningful responses in MDS patients.

When acute leukemia develops in patients who have had prior MDS, the leukemia has been commonly refractory to typical antileukemia regimens. In elderly patients with MDS-associated acute leukemia, many experts have advocated supportive management alone.

Aplastic Anemia

Aplastic anemia results from complete bone marrow failure with absence of stem cells resulting in severe decline of all cell lines. The disease is characterized by severe neutropenia, anemia, and thrombocytopenia, and the diagnosis is confirmed by bone marrow biopsy revealing a paucity of cellular elements.

Treatment is based on the degree of cytopenias, with blood product support and antibiotics if there is evidence of infection. Immunosuppressive therapy has helped to reduce transfusion requirements. Transfusions should be minimized and specifically avoided from family members to prevent alloimmunization in potential transplant candidates. Bone marrow transplant should be considered for all patients, although the published experience in older patients is limited and this approach is currently under active investigation.

See also: Cancer and Age.

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History of Aging

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Glossary

Gerousia – A council of men who were at least 60 years old.

Stem Families – Domestic units where young or old relatives would move into a middle-aged householder's residence.

Introduction

Old age embraces age-old, universal, diverse phenomena. While every culture past and present has deployed comparable terms or phrases to demarcate the life course's beginning and end, images and realities associated with the last stage of life have differed everywhere. Any historical generalization must take account of the influence of gender, class, race, ethnicity, and age. Growing older and becoming old thus have varied greatly from place to place over historical time. The range of meanings ascribed to old age and the conditions experienced by older people at any given time and place diverge enormously.

While historians can safely attest to the diversity in international historical perspectives on aging, it should be noted that scholars possess more cultural data than information about other aspects of aging. Except in mythology, no investigator has discovered evidence of a golden age in which older men and women lived in a bucolic Elysium. Yet our knowledge of the global history of aging is fragmentary. Not much is known about the socioeconomic conditions of the elderly, particularly those living below the equator and especially prior to the nineteenth century. We only have begun to describe and explain the plethora of positive, negative, contradictory, ambivalent, and ambiguous images and relationships that form the matrix of late-life opportunities and exigencies.

International historical perspectives on aging, moreover, do not always capture the full context that shaped senescence's voices and realities. Generational factors – whether the eldest son marries early or late and whether that affects inheritance patterns and living arrangements – influenced cohorts as they navigated the life course. Furthermore, the meanings and experiences of late life often are byproducts arising from political, social, economic, cultural, and demographic factors that shape a particular society at a specific historical moment. Far earlier in pre-industrial time than was once believed, older people in England maintained nuclear households until economic and physical necessity required coresidence. In Eastern Europe during the same period, however, stem families and complex housing arrangements prevailed.

Researchers, it must be added, have sometimes misread historical and cross-cultural evidence. Three decades ago, modernization theory was the template used by many gerontologists to describe and explain the pathways of aging. It was taken for granted that older people lived better in rural than in urban settings and that industrialization destroyed the extended household structures and reduced work opportunities for the aged. Dualisms characterized the international history of old age: before–after, good–bad, networks–autonomy. And insofar as developing nations were expected to follow, or at least emulate, the historical trajectory of North America and Western Europe, similar trends were presumed to obtain in due course. Recent scholarship has undermined historical patterns once limned as unidirectional or inevitable. Household structures and familial obligations have never been as monolithic in Asia and South Asia as was once thought: they depend on labor force patterns and the impact of public old-age relief, among other things. Indigenous traits matter; this makes the interpretation of the fragments of the past such a daunting task.

The Decline of the Aging Body: The Foundation for Perspectives on Historical Gerontology

With such caveats in mind, let us begin with the physical signs of aging and old age. The oldest known document referring to aging is a description by the philosopher and poet Ptah-hotep, writing in Egypt in 2500 BCE: "How hard and painful are the last days of an aged man! He grows weaker every day." (Gunn BG, trans., *The Instruction of Ptah-Hotep*, http://www.kensemedia.com/encyclopedia/ppp/instructions_ptah_hotep.htm (accessed 28 March 2006)). This characterization challenges notions that the elderly in primordial times lived healthily and happily. Ptah-hotep characterized physical aging as bodily decline, a universally recurring but not ubiquitous a theme in the history of global aging.

Men over 50, for example, thrived in Eastern households during ancient times. Confucius described moral development chronologically: "At forty I no longer had doubts; at sixty there was nothing on earth that could shake me; at seventy I could follow the dictates of my heart without disobeying the moral law." Maturity, declared Eastern sages, deepened an elder's affinity to family ancestors. So critical was age in the Confucian world view that older women prevailed over their sons and daughters.

Similar conditions existed elsewhere in the region. According to the Taoist tradition, extreme longevity was proof of sainthood. According to Brahaman canons, a few elderly hermits attained so much wisdom that their bodies were transubstantiated into immortality. Religious traditions, passed down from generation to generation, were thought to bind the old in a safety net. Yet in postwar Asia, most dramatically in Japan, demographic pressures and public policies have undermined the favorable status of late life.

Such respect for old age was not enduring in early Western cultures. Following Aristotle's lead as well as findings by physicians in the fifth century BCE, the ancient Greeks deplored late life's lamentable nature: they characterized older people's bodies as abnormally cold and dry, and their bile black, thus making death the natural consequence of aging. The ancient Greeks believed that specific diseases afflicted the last stage of life. Hippocrates catalogued old-age maladies – such as cataracts, nephritis, vertigo, apoplexy, and poor mental health – in his *Aphorisms* (400 BCE). Thus, Hippocrates anticipated the observation by Seneca (4 BCE–AD 65) that *senectus morbidus est* – "old age is a disease."

Greek images of old age were not resolutely negative. (Shades of gray color virtually all meanings and experiences attributed to aging in global history.) Sparta beginning in the seventh century BCE was ruled by a *gerousia*, a council of men who were at least 60 years old. Elderly leaders, selected for their wisdom, were expected to exercise authority conservatively. Yet abuse of power by the *gerousia* prompted satire by Aristophanes in the fifth century.

Like the Greeks, the Romans portrayed old age in contrasting hews. At one extreme, Virgil (70–19 BCE) in the *Georgics* and Juvenal (60–130 AD) in his *Satires* bemoaned its infirmities. Cicero (106–43 BCE), on the other hand, argued in *De Senectute* that years of experience more than compensated for the physical decline that came with advancing years: "Old age is usually not only poorer, but is even richer…old age, so far from being feeble and inactive, is ever busy and doing and effecting something."

Hebrew scripture provides another variegated treasure trove of late-life images and stories. "A hoary head is a crown of glory; it is gained in a righteous life," according to Proverbs (16:31). The fifth commandment not only demanded respect for elders, but also implied that children would be punished if they disobeyed their parents. According to the Pentateuch, longevity was the Lord's reward for faithful service. That Sarah and Ruth enjoyed the fruits of ripeness suggested that even in patriarchal societies, the advantages of age could accrue to women through God's graciousness. Other passages in Hebrew scripture, however, paint a gruesome portrait of physical decline, fear of rejection, and increasing vulnerability with advancing years that anticipated the contrasts secular writers made between a green old age and second childhood, as well as the more recent distinction that Bernice Neugarten posited between the young-old and old-old. Because living too long was risky business, prophets urged the children of Israel to care for helpless, decrepit widows.

This modest gloss on texts suffices to establish an important generalization: the physical aspects of senescence, sometimes linked to chronological age, lay the foundation for a perception, both international and historical, that people who attained old age declined in the process. Interpretations of this perceived reality varied. In the Koran, senescence meant "neither more nor less than one more sign" of Allah's power. In most traditions, people of all ages presumed that diminished capacity inexorably led to disease, dependency, and death. As Jonathan Swift observed, "every man desires to live; but no man would be old."

Folk artists between the fourteenth and nineteenth centuries designed graphic renditions of the steps of ages, wherein toddlers traversed up stairs and then adults descended another set of stairs to death. *Lebbenstreppe* were especially popular in central Europe. The number of steps ranged from four to thirteen. Icons differed for men and women, though some life stairs featured partners. Children played with toys. Boys carried books while girls learned to spin. Men in their prime were soldiers; women, mothers. Artists made their aged subjects stooped; the elderly were assigned sedentary duties. At 70 or 80 the old ones were confined to their beds, dependent on others while awaiting Father Time to turn his sickle (a symbol of fertility) into an instrument of destruction. The message was clear: youth rose in due course to displace the control wielded by their elders.

Diverse depictions of the physical manifestations of old age have passed down to the contemporary era, filtered through broader cultural and historical lenses. There has been no dramatic or sudden shift in

old-age imagery, although revolutionary situations tend to undermine prevailing images of old age. For instance, young Chinese intellectuals in the early twentieth century assaulted the centuries-old respect for age as part of their sweeping attack on Confucianism. "Youth is like the early spring," wrote a leader of the May 4th movement. "What is the struggle [of youth]? It is to exert one's intellect, discard resolutely the old and the rotten." Modern Chinese revolutionaries rejected longstanding deference paid to the old on account of their advanced age.

Sometimes physicians' clinical gaze validated popular perceptions of the elderly. Nobel Laureate Elie Metchnikoff in 1905 diagnosed old age as "an infectious, chronic disease which is manifested by a degeneration, or an enfeebling of the noble elements." Four decades later a different prognosis was offered by geriatricians: "Senescence is not all decline....With planned cultivation of these compensatory capacities, the increments can very nearly balance the decrements." Alchemists' attempts at prolongevity have proved ephemeral throughout the ages; nowadays public health, pharmacology, and modern science offer genuine hope that many vicissitudes of age might be controlled, if not eliminated. Indeed, some scientists go a step further, contending that anti-aging interventions can prolong healthful longevity, thus expanding the human life span.

One final, essential point on the physical ravages of age: although not articulated fully in the historical literature, since women for much of world history have been invisible in texts and missing from public records, a gender bias persists over time and across space in characterizing senescence. Ageism has affected older women more than men, in part because the latter possess resources that compensate for losing good looks. There are exceptions: while females typically play a subordinate role in the Muslim world, older women wield power and authority in Hausa sectors of urban Nigeria. And the derogatory term hag ironically comes from *hagia*, Greek for a holy woman. Still, contemporary culture by and large marginalizes older women, who comprise the majority in both developing and advanced industrial societies.

Demographic Patterns in International Historical Perspective

Just as the physical attributes of old age represent salient traits of the last stage of life, so too do the demographic realities of human longevity put numbers to its diverse dimensions. Anthropological and historical research suggests four generalizations about demographic patterns of aging:

1. Old people have existed throughout most of recorded history, but they have constituted a very small percentage of the total population in any given time or place – less than 2% of the total, usually far less. Reaching old age was a rare event when the odds of surviving to age 1 were poor. Only one in three babies survived their first birthday in Bombay at the beginning of the twentieth century. If a person reached the age of 20, then his or her chances of surviving to age 40 and beyond were significantly improved.
2. Since at least 1700, written records in Europe and North America (such as laws, diaries, and encyclopedias) have loosely placed the onset of chronological old age around 65, give or take 15 years. There is little evidence indicating that chronological old age occurred before age 40, though ethnographies of contemporary Sri Lanka report age-related decrements at that age. Men and women who controlled physical and economic resources, and who gained favorable status through the tasks that they performed, were considered to be in their prime. The Chimu kingdom in Peru at the time of the Spanish conquest, for instance, considered warriors between the ages of 50 and 60 to be 'half old.' After 60, individuals paid no tribute and were exempt from military service.
3. The greatest increases in life expectancy at birth and in life expectancy at age 40 have occurred in the twentieth century. Since 1950 there have been modest gains in life expectancy at age 60. Three-quarters of all gains in longevity have been attained since 1900. Since the end of World War II, sharp declines in fertility rates have been a major factor increasing the proportion of old people in a given population.
4. Along with gains in adult longevity has been the aging of population structures themselves. Rates of societal aging vary among and between mature and developing nations. Thus, Japan, which as late as 1950 had only 5% of its population over 65 now has the greatest percentage of elders in its midst, surpassing even Sweden. Life expectancy in Japan rose from 50 to 78 for men, and from 55 to 83 for women from 1947 to 1995. "From a historical perspective population ageing represents a human success story," contended a National Research Council report (2001). "At the same time, the sustained shift in population age structures poses an array of challenges to policy makers."

These generalizations affect in at least two ways how people around the world have perceived aging and how older people have interacted with younger persons. Consider first that, until recently, few human beings attained old age. The paucity of elders consigned them to the role of strangers in the land of the young – and even to themselves. "Old age is the most unexpected of all things that happen to a man," declared Lev Trotsky, age 56, in 1935. Dubiety has historically made for ambiguity in human interactions. Strangers can pass unnoticed in crowds. In rural settings they can get by if local residents are hospitable and helpful. Where norms and mores associate a healthful manner of living with the virtues of a ripe old age, elderly men and women are presumed to be assets unless their actions suggest otherwise. Some elders put a spin on this idea, writing their own scripts: Thomas Jefferson, arguably America's greatest sage, and Maggie Kuhn, the founder of the Gray Panthers 150 years later, both exulted in their 80s about the pleasure of outliving their opponents, thus having the last word.

Yet even healthful longevity is a double-edged sword. Viewing the aged as strangers has lent itself to a less sanguine interpretation of aging over time – one of wariness, even fear. Just as many people treat aliens with suspicion, projections and fears cause older persons to be viewed as potential witches or burdens on the community. Legends and case studies indicate that parricide has occurred in places with scarce resources. Portraits of age drawn by elders can be as gloomy as the ones younger people imagine. John Burroughs, shortly before his death at age 84, wrote: "The octogenarian has no alternative but to live in the past. He lives with the dead, and they pull him down." Survivorship amid frailty and poverty without a sufficient support network brings the risk of rejection and dependency.

Second, it is worth noting that old age's prescribed span of years has always been perceived as longer than the boundaries of any other stage of life. Infancy lasts no more than 2 years; adolescence nowadays rarely stretches more than two decades. But the benchmarks of late life encompass much of the life course. In some countries people can qualify for old-age privileges at 50. Alternatively, some elders are successful in denying that they are old: after reaching 80, Bernard Baruch persistently claimed that old age began at his current age plus 15 years. Elastic thresholds make old age the most heterogeneous stage of life. In part this explains why past generations of elders differ in physical, mental, psychological, and social capabilities. Two people at the same age in the same place and historical moment may share no other common attribute than the number of years they have lived. Such diversity has always existed across cohorts. Some people mature fruitfully as they grow older; others decline slowly; still others are victims of an unexpected mishap. Many older people try to maintain lifestyles that they adapted in middle age. Others opt, by choice or circumstance, for radical changes in what they think, feel, live, or do. Some move on; others become stuck in helplessness.

The heterogeneity that inheres in late life may have grown richer in recent decades. A subtle revolution is in the making, which results from societal aging. With the years added to adult life expectancies since the mid-nineteenth century, age-based differences within elderly populations everywhere have widened. When the aged were few in number, their problems were manageable. It mattered little if the potential contributions of the aged were squandered. Now that the elderly are an increasingly larger subset of the population, their wants, desires, and needs can no longer be discounted. Senior citizens represent a potent voting bloc, one entitled to governmental support. People during the past century came to believe that they would reach the age of 65. They considered a good retirement a right. These demographic and economic expectations alone justify the hypothesis that the great watershed in the history of aging, particularly in developed countries, occurred during the twentieth century.

Family Ties

Regardless of historical moment or geographic location, family members have always been the primary line of defense in situations of old-age dependency. Structures diverge notably over time and by setting. In western European nations and North America, the elderly (usually men) have traditionally wished to remain heads of their own household as long as possible. This generalization requires at least two qualifications. First, in the early modern period, some domestic units (temporarily in Western Europe, longer in Eastern Europe) became 'stem families' – young or old relatives would move into a middle-aged householder's residence – an arrangement that typically lasted for a short duration. Second, more emphasis has been placed lately on the autonomy than on the independence of family elders. Nuclear families typify the Western model: older people maintain their residences as long as possible.

Elsewhere, very different arrangements obtain. In Africa and parts of Asia, elderly women often headed family units. Daughters-in-law either resided in the abodes of their mothers-in-law or they lived in close

proximity in order to conform to her domestic plans; women who lived in their husband's village viewed the arrangement as a temporary enclave. Deference to elders animated pre-industrial Japanese families, where permanent members ranked ahead of temporary residents, men ahead of women. Aborigines in Australia opted for more open arrangements, so fathers might be fictive kin, and middle-aged persons might be elders since they controlled local matters energetically.

Whatever the domestic arrangements, women have been more likely than men in virtually every historical setting around the world to be the primary caregivers for older people. In some places the responsibility fell to the youngest daughter. Sometimes aunts or female cousins fulfilled the tasks of cooking food, bathing, or cared for an infirm elder. In rural Japan, public and private rituals of concern traditionally have been gendered. Men typically participated in domestic matters only when there was no alternative.

Some safety nets develop holes. Estrangements and divorce can disrupt caregiving plans. Designated caregivers may move with their spouse out of their community to a place too far away to be able to serve. Poverty strains resources. Death breaks bonds. In such situations, neighbors and friends take over on an informal basis. In modern times, compensatory arrangements exist. New modes of transportation and communication have enabled siblings and children to remain in touch with their elder kin even if they are not in physical contact daily.

Societal aging has disrupted traditional familial patterns in at least three other ways. In the East, skyrocketing real estate prices have made it impossible for family members to cohabit in commodious space. Elders in Japan and China now make hard choices about residency like their contemporaries in the West. Second, many women are unwilling or unable to serve as primary caregivers for elders because they are gainfully employed outside the household. Finally, the traditional pyramidal family structure has, with multigenerational survivors, come to resemble a bean pole. There are now more elders available to assist with caring for the chronically impaired or very old, but divorce, relocations, or the caregiver's own failing health may preclude the ability to assist.

Economic Patterns

Agricultural pursuits, which have been the most prevalent mode of economic activity everywhere throughout recorded history, generally provide favorable opportunities for elderly men and women. Farming is hard work, especially at harvest time. Nonetheless, there are many tasks entailed in keeping a farm running that can be accomplished by people with diminished capacities – if they have the requisite expertise. For example, the aged can supervise the work of others and keep records. The insights accrued over a lifetime of observing nature's bounty and brutality have historically solidified the popular perception of the elderly as veterans of productivity.

Control of the land, moreover, assured older people a measure of economic security. Children worked the land for their parents or grandparents with the expectation that in due course they would gain title to the family property. Elders wisely transferred property only after making due provisions for themselves in their declining years or for a spouse's widowhood. Studies of inheritance patterns and the provisions made for widows, however, require case-by-case analysis, for we still know far too little about the roles of kin networks in property transfer. Nor do we have more than anecdotal evidence about the ability of the aged to assure their well-being through other means. Healing powers and the magic of Shamanistic rituals accorded the aged prestige in Native American tribes, but more work must be done before a historical generalization is warranted.

After the Industrial Revolution, the economic status of older people changed, for better and for worse, especially insofar as new modes of production and consumption altered prevailing ways of doing business. Economies of scale made hand-made goods a luxury. In a world dominated by bureaucratic procedures rather than personal or familial connections, it became more difficult for elders to adapt to the changing marketplace. Many old workers became obsolescent. At the same time, however, men over 60 who managed or owned railroads, steel mills, or other profitable corporations controlled a disproportionate share of the nation's wealth. And home purchases in late life indicate that members of the working class benefited from the new order.

In the initial phases of industrialization it was common for workers and manager to treat the aged as if they were disabled. Superannuated workers joined the lame and blind in begging for money at the factory gate or in the saloon. By the middle of the nineteenth century, progressive banks in Britain and transportation companies in the United States began to offer pensions based on an employee's age and years of service. Retirement became both a reward for faithful service and a tool for getting rid of worn-out workers. Corporate pensions were deemed gratuities in the boardroom; only after the governments established their own Social Security measures did the financing of corporate and union pensions become regularized and regulated.

It has always been possible for older people to retrain themselves for new positions in a changing marketplace. Various private organizations, beginning in the mid-eighteenth century, established lyceums and adult education programs to teach older people new skills or to enrich their days with learning opportunities they did not have earlier in life. Such programs may become increasingly significant in the future, but their success in reintegrating older workers into the marketplace thus far has been modest.

A dramatic change in late-life economic patterns over the past 50 years has been a consequence of women's growing participation in the paid workforce. Traditionally, young women worked before they married; widows became bartenders, inn keepers, or laundresses to make ends meet. Career women, like men, now seek part-time or seasonal employment in their later years. Continuing to work is not always a desideratum: women work by necessity because they live longer on average than men; sex discrimination compounded by ageism impedes their career opportunities and salary potentials.

Indeed, the plight of older women workers is simply the latest phase of a general economic late-life pattern. People have always expected the aged to make provisions for their old age. Generally, this has meant that the old had to work until they were disabled or dead. Pensions, public and private, have made it possible for people to look forward to a sunny retirement. But for most humans internationally and historically, the dream of genuine economic security has not been realized. A majority of older persons have lived at subsistence levels, rarely confident that they could or would outlive their resources.

Political Developments

We have already noted that the elderly everywhere throughout history have held many important leadership positions – in African and Southeast Asian tribes, in the papacy and episcopacy, and in democratically elected offices. The aged putatively have the requisite experience, having risen through the ranks, and the wisdom, having dealt with all sorts of situations and personalities. Despite the gradual aging of most populations, however, there has been no universal preference for making older persons leaders. That said, age discrimination is not rampant. Experience counts in heated contests.

The most important political old-age development has been in the area of social welfare. States provide for those aged considered deserving and/or needy. Public old-age relief typically began in the local community. Institutions such as a religious organization or charity set aside funds (thereby supplementing resources provided by family, friends, and neighbors) to shelter, feed, or provide medical care to elderly indigents. Over time, local entities – the country, a city, a state, a district – made allocations, sometimes also erecting facilities to house the old. State governments or regional polities provided a third layer of non-familial support; municipalities granted pensions to their employees, and smaller government units gave assistance to the elderly poor who met stringent eligibility requirements.

Military or veteran's pensions have been important sources of old-age relief. The precedent for giving loyal bureaucrats retainers so that they might become superannuated dates back to twelfth-century China and fifteenth-century France. By the 1800s, poor, aging veterans began to qualify for stipends or land grants comparable to those awarded to wounded soldiers and sailors. Allocations were not insignificant: by 1913, for instance, pensions to northern Civil War veterans represented 18% of the US federal budget.

In the twentieth century, virtually every nation has enacted some sort of old-age assistance program to deal with dependency and launched old-age insurance plans to enable workers to prepare for their later years. The introduction of old-age pensions in Ireland and elsewhere did not affect residential patterns, though it did bolster family wealth. The historical timing and scope of such schemes depended on the country's population structure, the ideology of the ruling party willing to enact such provisions, and the treasury's current and anticipated funds. The growth of old-age interest groups ensured the liberalization of public benefits. Until very recently, Social Security measures in the United States and Western Europe enjoyed widespread popularity. With population aging and the staggering cost of elder care, however, many nations (rich and poor) are rethinking the entitlements that government officials feel that they can afford to contribute to the well-being of elderly citizens.

Cultural Aspects

This article began by emphasizing how images of bodily decline generated unfavorable perceptions of old age; it ends with a brief overview of how cultural traditions have sometimes enhanced the status of old age historically and internationally. Late-life wisdom and experience count in agricultural settings, in certain political milieu, and in religious institutions. Kin ties often improved work opportunities in urban settings. The elderly, especially men, have retained and increased their power as long as they remained vital. Some, like the Ayatollah Khomeini, dominate revolutions.

The young have typically respected the value of aged mentors. They count on the stories that elderly men and women tell to help them to clarify options and to identify pitfalls that lie ahead. Customs are transferred from generation to generation. The historical record suggests that senior professors, elderly clergy, and retired military sometimes have been recruited in times of crisis to assist younger leaders.

Postmodern cultures of consumption have attempted to manufacture perceptions of a good old age in order to capitalize on the wealth of growing numbers of older men and women in aging societies. Confectioners and card makers have tried to commercialize Grandparent's Day as successfully as Mother's Day or Father's Day. So far such efforts to tap the gray market have not borne much fruit. Advertisers do not know how to reach their intended target. The most memorable media images, in fact, are those depicting 'greedy geezers,' well-off, narcissistic, elders squandering resources that rightly should go to rising generations. Robert Butler coined the term ageism to identify a prejudice comparable to sexism and racism. Contemporary ageism is not the same as Ptah-hotep's, but it serves to remind us that humans everywhere tend to value those (again, there is a gender bias) who demonstrably contribute to other people's well-being. People of all ages tend to disesteem those whose vulnerabilities cannot be masked by a sunny disposition, good health, and economic well-being.

We are entering a new phase in the history of aging, shaped by a long past of cultural and structural lags in integrating the old into communities. Cross-domain relationships – between health and retirement decisions and between family structure and well-being in older age – have always mattered. History provides a baseline to imagine our future selves, but the lessons of the past are apt to be conflicted and unsettling.

See also: Life Course; Retirement.

Further Reading

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History of Gerontology

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Glossary

Aging – The process of change or transformation of the young to the old organism. The term refers to the patterns of change that occur with age in genetically representative organisms living under representative environmental conditions.

Apologism – The conviction that the study and manipulation of the body to produce greater longevity is a violation of the natural or cosmic order.

Geriatrics – A branch of medicine specialized in the care and treatment of the diseases and health problems of older persons.

Gerontology – The study of the phenomena of aging from a research and scholarly perspective. It embraces studies from the biological, behavioral, and social sciences.

Senescence – The biological process of growing old associated with an increasing probability of dying and susceptibility to disease.

Introduction

Gerontology is an ancient subject but a recent science. In the earliest recorded histories there is evidence that humankind speculated about aging and the association of infirmities and death with advanced age. The processes of aging are complex, and combined with the uncertainties about death, a fertile ground for myth, fantasy, and wishful thinking has always existed. These speculations have given rise to myths about the prolongation of life and the nature of death, Some elements of these myths have been displaced by information provided by scientific research but many still remain as part of our cultural inheritance.

The word gerontology was introduced in 1903 by Nobel Laureate, Elie Metchnikoff (1845–1915), professor at the Pasteur Institute of Paris. Although the word gerontology is of relatively recent origin, there were many early scholars who published their observations and thoughts about why the human organism changed in appearance and in function, and the likelihood of death with advancing chronological age. Gerontology refers to the study of aging, research, and scholarship in all its aspects. The word is derived from the Greek word for an old man, *geront* or *gerontos*; plus the suffix logy, which refers to a branch of knowledge or science. The term *geriatrics* refers to a branch of medicine that specializes in the care and treatment of the diseases and health problems of older persons.

From archeological studies of the careful entombment of persons in preliterate times it is apparent that in many cultures a great deal of thought was given to the transition from life to death and to prospects for life after death. In those cultures, care was taken in the manner of burial and in providing accompanying articles that might be useful in a future existence. Although one can only speculate about what our preliterate ancestors thought about old age and aging, their ideas were undoubtedly carried over into many of the earliest written material.

Gerontology and its background may be divided into several periods: (1) the mythic period from prehistory to the Greco-Roman era; (2) the philosophical period, from Greco-Roman days to the Renaissance; (3) the Renaissance; (4) the early scientific period, from about 1600–1800; (5) the expansion of empirical research, from 1800 to about 1930; and (6) modern gerontology. These eras are not sharply demarcated and it might be argued, for example, that the period of modern gerontology begins somewhat later than 1930 when gerontological societies were formed. For example, the Gerontological Society was founded in 1945, later renamed the Gerontological Society of America, and the International Association of Gerontology about 3 years later. Such dates might be used to mark the beginnings of the modern era, although, as will be pointed out later, activities in the 1930s provided the background for this emergence.

The Mythic Period

From very early writings it may be concluded that humankind has always speculated about the causes of events and offered explanations that attributed causality to mythical forces. Aging is no exception. Gruman prepared a useful history of thoughts about aging and longevity and compiled an extensive bibliography of the mythology of aging with descriptions of the flow of ideas from ancient times to 1800. One of the earliest writings that discussed aging is the epic of Gilgamesh that Gruman dates to around 3000 BC. The hero of this Babylonia poem, Gilgamesh, becomes obsessed with the thought of immortal life and of finding the secret to it.

As ancient people saw others grow old and die and observed changes in themselves they wondered how they might avoid death. One mythic explanation is that humans once had the gift of immortality but lost it in a fall from grace by offending the gods or God. This led people to attempt to regain immortality by pleasing the gods, offering sacrifices, praying, or doing heroic deeds in accord with the customs of their culture.

Other myths were that people living in remote parts of the world still retained the secret of very long life or that somewhere there were healing waters, and bathing in them would restore youth if not bestow immortality. Throughout the ages, such myths have led to geographic explorations to find fountains of youth, though these have never yielded the sought-after secret cure or reversal of aging.

Gruman divided the myths about aging and mortality into three main types: (1) antediluvian, which hold that in the past people lived much longer; (2) hyperborean, in which it is believed that people live much longer in some remote part of the world; and (3) the fountain type, in which healing waters or substances are thought to exist somewhere. Gruman also uses the word prolongevity to refer to the myths and legends in which longevity is extended by means other than those under humans' control.

Myths about longevity have usually been linked with a belief in an 'Abode of the Blessed,' where the pure have extended life. Elements of this pattern have been widespread, appearing in Persian, Teutonic, Japanese, Hebrew, Hindu, and Chinese myths.

Alexander the Great (356–323 BC) is described as having had an encounter with a fountain of life and

Ponce de Leon (1460–1521) purportedly discovered Florida while looking for a fountain that the North American Indians believed was rejuvenating to those who drank or bathed in its waters. It is surprising how many cultures have passed on legends that describe rejuvenating waters that flowed out of an earthly paradise or described mysterious substances that have the power of prolonging life. Myth and magic and wishful thinking about longevity and death apparently pervaded all societies in prescientific eras.

Today these myths may still underlie the popularity of healing spas, diets, exercise programs, and vitamins of special potency. This comment is not meant to express an evaluation of the validity of ways of modifying the course of aging but to express a link between these high contemporary interests and the underlying fear of old age and dying that must have preoccupied some of our preliterate ancestors and still are important to our contemporaries.

Less available to Western scholars have been the East Indian legends, myths, and perspectives on old age and death. A review of East Indian perspectives on aging and the meaning of life has been provided by Ram-Prasad, in which the ideal life pattern is described as consisting of four stages: studenthood, householder, forest dweller, and renouncer. Codification of what students needed to learn began relatively early, from 1500 to 500 BC. By the beginning of the Christian era an Indian system of belief had evolved that encouraged conformity to these four stages of the life course. Individuals were expected to fit into a cosmic order, *dharma*. Ram-Prasad describes dharma as being an overall entity that reflects the regulation of all aspects of the cosmos. The law book of ancient India is the Code of Manu. It is of interest that early phases of life include pleasures and increasing wealth, but later phases require detachment or renunciation. Meaningfulness in later life is attained by a transcendental detachment from the requirements of daily living. As an alternative to the transcendental detachment in the later years, one may attempt to derive meaning from world-directed acts; however, in the classical East Indian view of life, in the final stage of life, old age, the individual transcends and renounces the world.

In Hinduism and Buddhism, there is the tenet that the force developed by an individual's actions, *karma*, provides the energy for the series of rebirths and deaths until the individual achieves spiritual liberation. Reincarnation in a different body form represents the transmission or embodiment of the soul into a new structure. The reincarnated form would be an outcome of the individual's actions during a previous life.

East Indian thought about old age and death accepts the idea of a preordained cosmic order in which the individual lives through stages en route to some ultimate transcendental state. Thus the background for Indian thought is a mixture of philosophy, religion, and the mythology of a long-existing culture.

There has been some filtration into the West of the idea of reincarnation, though the West has been influenced by the Christian view that the individual is ultimately resurrected for eternal life. Both Hinduism and Christianity regard the conditions of future existence as being a consequence of present moral behavior.

Greco-Roman Philosophers

The Greek and Roman philosophers dealt with questions about the nature of aging and death. The contributions of philosophy and the beginnings of science derived their strength from the rigor of the reasoning and its logic but not data. Underlying their views is the realization from personal observations that there is a pattern to changes in life marked by stages, cycles, or seasons of a life. Increasingly, in the Greco-Roman views of life there was a separation of the physical or physiological aspects from the moral or religious points of view.

In the fourth century BC the Greek philosopher, Epicurus (341?–270 BC) thought that if people developed the right attitude about the end of life and death, they lost their fear of them and lived a more peaceful life. According to Gruman, Epicurus thought that a short life could be just as happy as a long one so that prolongation of life was not important. Aristotle (384–322 BC) was more interested in the natural phenomena of old age and thought that the old body was cold and dry leading to death. He had a rather fixed view of cosmic relationships and avoided the idea of humankind's rebelling against nature or attempting to ameliorate the course of aging.

Cicero (106–42 BC) thought that death was a blessing because it freed our immortal souls from their bodily prisons, and he attempted to rebut major objections to old age, including the one that old age interferes with the enjoyment of sensual pleasures. He expressed the opinion that this is a good loss because it permits the older person to concentrate on the promotion of virtue and reason. According to Cole, the Greco-Roman philosophers' worldview of old age was that it was inexorable.

> Beginning at conception, the physiological process of drying out and growing old, continued inexorably until death. The stages of life were nature's milestones, marking the diminution of natural heat and increased desecration.

> Each change dictated its own behavior pattern. This approach to aging and the life cycle took shape in an intellectual world without boundaries between science and philosophy; hence it combined the physical and the moral, interpreting behavioral signs in the light of physiology as well as individual character. (Cole, 1988: 49).

In addition to the philosophers of the era, physicians also contributed their observations about the course of life and the afflictions of the body. The most significant of these was Galen (129–199), who became a model for physicians and for medicine. He believed, like others of his time, that the body dried out as it grew old. Although this suggests that the adding of moisture to the body might extend life, he did not attempt to interfere with what were regarded as the inevitable changes in the body's balance of heat and cold and the drying out of tissues. Two elements in early thought about aging led to the position that attempting to modify the course of life is undesirable. The first of these is that it is against the will of God, the second is that it is against the law of nature. Gruman said that "Galen's writings are dominated by teleological arguments, which emphasize that nature always acts for the best. To the question whether old age is a disease, Galen replied that, 'it is not a disease because it is not contrary to nature'" (p. 17).

In the late Middle Ages, Galen's interpretation of the biology of life was shared by an Arabic philosopher and physician, Avicenna (980–1037). He believed that the drying-out process began in the embryo and continued as a beneficial influence until growth and development ceased at about the age of 30. It was further thought that as the innate moisture of the body dries up, its innate heat decreases, and the aging body becomes cold and dry. This led to a pessimistic outlook about the capacity of medicine to interfere in the decline of function of an aging body. It was thought that extending the life was not a legitimate medical goal, because each individual had a predetermined fixed term of life.

All societies and cultures have been impressed with cycles of the life span and its conclusion with death, although the interpretations or attributions of the forces behind patterns of change have varied. The Greeks and Romans and the Hindus believed that death was part of a natural cosmic order. In Christianity, a different causal attribution was made, that because of sin humankind had fallen from a state of grace in the Garden of Eden and lost immortality and was destined to live a life on this earth plagued by many problems. Eternal life could come only after death and after a life lived according to religious tenets. For many centuries religion and the practice of medicine shared similar views of the preordained character and length of human life.

The religious and theological underpinnings of Western medieval life encouraged the view that one should not tamper with God's will. This position not only discouraged attempts to modify the course of life but also discouraged science generally because its attempts to understand nature were intrusions into the organization of the cosmos as designed and desired by God. Although both the Old and the New Testaments project the view of the fall of humankind and the loss of immortality due to sinfulness, the resurrection of the righteous for eternity is emphasized in Christianity and the New Testament. This views the human body and its afflictions as of little importance in comparison with the soul, which is eternal. Victory over death was achieved by resurrection and eternity by God for the righteous. Translated into the attitudes of educated persons, this discouraged experimentation and explanations cast in terms of natural causes. If one attributes the downfall of humankind from Eden as based on pride, then pride is the paramount sin of the scientist because scientists presume to be able to ascertain causal relationships and thereby God's purposes.

Gruman contrasted apologism and prolongevity. The position of the apologist is essentially that study and manipulation of the body to produce longevity is a violation of the natural order. If humankind became mortal and died because of sin, attempts to modify the course of life are not only likely to be unproductive but they are presumably sinful in and of themselves. By extension, old age and death are beneficial in that it brings us closer to resurrection and eternal life with God. The apologist's position not only deterred the development of science, but it also discouraged the transmission of earlier myths about eternal life that had been passed on in the folklore of many cultures. Just below the surface of medieval society, however, there was evidence that early myths still persisted about eternal life and legendary places in the world where long life was attained. Columbus, for example, in 1498 reported that on his third voyage he located a terrestrial paradise in Venezuela. A relatively recent novel, the *Lost Horizon*, by James Hilton, deals with the myth of Shangri-la. This was the name of a place in the Himalayas where people reportedly lived a very long time.

Medieval theology did not stamp out the desire to believe and perpetuate myths of eternal life on earth or an interest in finding pathways to increase longevity. It did, however, discourage the study and gathering of systematic data on the conditions of life that might lead to life extensions.

In the sixteenth and seventeenth centuries in France and Austria, the Huguenots, a Protestant sect, were expelled and persecuted for their beliefs that encouraged a look at the natural sources of conditions of human life. At that time, the Roman Catholic Church, which dominated Christianity, did not favor the collection and examination of data on the length of human life and its variations in different places and conditions. As recently as the eighteenth and nineteenth centuries, there was evidence that the dominant theology of the West discouraged an empirical approach to demography and epidemiology that could ascribe the length of life to natural phenomena.

Unlike the mythic period, the Greek and later philosophers entered into disputations about their conceptions of aging. Lacking evidence from empirical science, it was the tightness of their logic or elegance of their reasoning that were translated into proof of the validity of their opinions. This was a marked advance in understanding because it brought the circumstances of aging into normal discourse and its causes into disputation rather than leaving them in the hands of temple priests who assigned causes to deistic power or offenses. The philosophers coupled their everyday observations with their abstractions in attempting to weigh evidence before arriving at conclusions. One of the early observations was that in death the body is cold. Hence the loss of heat became an early focus. Aristotle regarded old age as the time when our heat is diminished. Much later this same idea was expressed by Benjamin Franklin (1706–1790), who thought he could rejuvenate a dead chicken by exposing it to a spark of lightning (i.e., heat).

The Renaissance

The fourteenth century was the beginning of a revival of literature, learning, and art in Western Europe. Stimulated by the prosperity of the Italian economy and its culture many new expressions were spawned in art, literature, architecture, and science. In the sixteenth century, the Renaissance was joined by a Reformation movement in which Protestant churches separated from the Roman Catholic church. The Reformation brought with it a new freedom of thought but also new tensions about social controls, religious beliefs, and desirable life activities, though it still carried with it an emphasis on doing good works during one's lifetime.

There are many exceptions to this simple view of the evolution of Western ideas about aging and death. Medieval alchemists thought about prolongevity and apparently had done things to lengthen life. In China, there was no theological resistance to the exploration of natural experiments, and their alchemists also attempted to modify the course of life by using various natural substances.

In the Old Testament of the Bible, there is an account of the attempt to rejuvenate the aging King David (c. 1000–762 BC) by placing a young virgin in his bed. There had long been an assumption that inhaling the breath of a young maiden was a stimulus to longevity. This practice, called *gerokomy*, was recommended by a seventeenth-century Dutch physician who suggested that an aging burgomeister lie between two young virgins, presumably so that he would obtain maximum benefit, to restore his vitality.

The influence of the Renaissance and the Reformation freed investigators to pursue the gathering of data. Data or information could then be used for sorting out valid from invalid views of the causes of natural events. The use of data probably distinguishes more than anything else the approach to present-day thinking in contrast to that of the Greeks and Romans (i.e., it is not only logic and richness of thought that matters but the availability of data on which to revise thought). It also differs from classical East Indian thought about old age and death, which is based on the assumption that there is a preordained cosmic order in which each individual lives through stages en route to some ultimate transcendental state. Thus, the background for Indian thought is a mixture of philosophy, religion, and the practices of a long existing culture, although it did not stimulate scientific research on aging.

In Great Britain, the views of Francis Bacon (1561–1626) encouraged the growth of natural sciences and serious inquiry into the processes of aging. In Italy in 1558, Cornaro (1284–1367) published his *Discourses*, which was very influential in Western Europe. Cornaro believed that longevity could be extended by simple reforms of an individual's life habits. He believed that some very simple hygienic practices would influence the length of life and the condition of a person's health. This view has its counterparts today, that personal dietary habits, exercise, and activity patterns, exposure to noxious environmental influences, and stress influence how long and how well we live. The Renaissance and Reformation permitted a shift in attitudes that supported the growth of natural science and the gathering of systematic data. Although the observations of Galileo (1564–1642) on the organization of the planetary system led to a conflict with the Roman Catholic Church, later observers were able to interpret the organization of the planetary system with impunity and freedom from persecution.

The Scientific Era

As learned scholars began to make systematic observations in areas other than astronomy, a burgeoning period of science ultimately reached the subject matter of aging. In England, Isaac Newton (1642–1727), a member of then-religiously dominated Trinity College, Cambridge, explored physics and developed laws about the force of gravity. His life exemplified both the quest for understanding in natural terms and the conviction that relationships can be expressed lawfully. Scholars believed that every event or act is the inevitable outcome of its antecedents. The successes of astronomy and the physical sciences in explaining natural phenomena encouraged the growth of science in new directions in biology and medicine. Scientists had the conviction that everything was knowable, all things were deterministic and lawful. This encouraged the growth of new perspectives on the issues of aging, longevity, and death.

The expansion of mathematics and sciences occurred rapidly after the seventeenth century. European universities added many faculty members whose expertise and commitment were to science. This expansion originated in the physical sciences. It was followed by biology and then by psychology and the social sciences, although some remaining unease was experienced in the relationships between philosophy, theology, and by the growth of the behavioral and social sciences. As late as 1937, philosophers at Oxford University stated there could never be a science of the mind and voted down the creation of a department of psychology. Less threatening to the belief structure of organized religion was the study of mathematics, chemistry, and physics than was the study of human behavior.

The studies of British biologist Charles Darwin (1809–1882) perhaps epitomize the weakening of philosophical and religious presuppositions in characterizing the status of humankind in the universe. Through his observations of various species, Darwin concluded that there had been an evolution of species from simple early forms to later more complex species, including human. Although this did give humans a superior position in the sense that it was a late evolved species, it clearly broke with the creationist tradition, which regarded humankind as a unique and immediate purposive product of a Divine Being (*see* Evolution and Comparative Biology).

In 1825 Gompertz published his paper on the lawfulness of human mortality and age. He described the relationship between age and death rates, now often referred to as Gompertz' law. He pointed out that death rates fall from birth to about age 10 and then rise and accelerate until the end of the life span. His quantitative description of the life course of mortality was a lasting contribution to the study of aging. It should be remembered, however, that the quantitative description of the course of death rates over the life span does not in itself reveal the causes of mortality.

The expansive period of science in the nineteenth century was based upon the conviction that all phenomena of nature are lawful and that these laws can be determined through scientific investigation. The first application of this point of view in the study of aging was done by a Belgian scientist, mathematician, statistician, and astronomer Adolphe Quetelet (1796–1874). He published his views with supporting data in Paris in 1835. The translated title of his book is *On Man and the Development of his Faculties*. The determinist point of view is clearly expressed in his provocative opening: "Man is born, grows up, and dies, according to certain laws which have never been properly investigated, either as a whole or in the mode of their mutual reactions," (Quetelet, 1842, Edinburgh translation). Quetelet was a distinguished scientist of his day, and he visited and corresponded widely with other leaders in science in Western Europe. It is of interest to note that it is difficult to classify him in terms of contemporary science. He wrote and studied at a time before there were few formal university departments in many of the disciplines. He could be regarded as one of the earliest quantitative workers in the field of exact social science, but he also dealt with issues of mortality and functional capacities. Trained as a mathematician, he developed the concept of "the average man" around which were distributed measurements according to the law of accidental causes. In this he anticipated the work of Gauss, whose work on the binomial distribution, which is commonly known as the normal or bell-shaped curve. Quetelet reviewed mortality data in relation to age, sex, urban, rural, and national differences. He was convinced that little is beyond knowing if one attends to observation and to describing statistical and mathematical relationships. He clearly adopted a deterministic and organismic perspective about human development and aging. In commenting about previous work he said

> But they have neglected to put forward, with sufficient prominence, the study of his physical development, and they have neglected to mark by numbers how individual man increases with respect to weight and height – how, in short, his forces are developed, the sensibility of his organs, and his other physical faculties. They have not determined the age at which his faculties reach their maximum or highest energy, nor the time when they commence to decline. Neither have they determined the

> relative value of his faculties at different epochs or periods of his life, nor the mode according to which they mutually influence each other, nor the modifying causes. In like manner, the progressive development of moral and intellectual man has scarcely occupied their attention: nor have they noted how the facilities of his mind are at every age influenced by those of the body, nor how his faculties mutually react.

His perspectives on aging as resulting from ecological interactions of heredity, behavior, and the environment are congruent with late twentieth-century thinking.

Quetelet had been in contact with Charles Darwin's cousin Francis Galton (1822–1911), another outstanding intellectual pioneer of the nineteenth century. It is of interest to note that both of them were interested in quantifying the relationship of functional aspects of organisms with the age of the organism. Galton like Quetelet had broad interests. He was originally trained in medicine and mathematics and later studied geography, anthropology, and psychology. He became increasingly interested in anthropometric measurements and, like Quetelet, included measurements of physical and mental functions in his research.

An Englishman, Galton sponsored an exhibition of health in London in the 1880s and gathered considerable data on such things as the upper limits of hearing and changes that occur with advancing age. Galton used the term human machine, which undoubtedly reflects his earlier background in physiology. He was interested in fitting the facts of both development and aging in human beings into a broader framework of human evolution and science. One of his major contributions to the study of aging was his gathering of data at the International Health Exhibition of London of 1884. Over 9337 males and females aged 5–80 years were measured on 17 different functions. Because of his exposure to large masses of data, Galton developed an index of correlation to measure the degree of association of two variables (e.g., age and strength). This was a large step forward because it enabled scholars to separate factors according to the degree to which they were related to age or to some purported causal factor of aging.

Galton was very impressed with the power of biometrics and left his personal fortune to create the first university chair of biometrics. Karl Pearson (1857–1936) was its first occupant who extended the statistical methods for the analysis of research data, including the development of a quantitative correlation measure whose limits of error could be specified. Galton's interests later turned away from the study of development and aging to the application of Darwin's ideas of evolution. He attempted to develop principles of eugenics for application in the population at large. He wanted to encourage selective breeding of the population so that persons with high intelligence levels would have more offspring. In the nineteenth century, studies of aging were carried out by men like Galton and Quetelet who had high social status and who had the personal funds to finance them. There were no major organized laboratories that conducted research on aging for significant periods of time. Shortly after Gallon's work, a physician at Cambridge University, Humphrey, conducted a major survey of the health of older adults. The work, although admirably pioneering and comprehensive, lacked the quantitative synthesis provided by Quetelet and Galton.

In America, the statesman Benjamin Franklin (1706–1790) had earlier stimulated considerable speculation about reviving organisms that were showing no signs of life but might still be resurrected. Because of his involvement with the discovery of the lightning rod and thereby controlling the flow of electrical discharge, he thought that the loss of electricity or the loss of vitality might be the cause of aging. This example underscores many uncertainties in the field of gerontology. That is, it is uncertain whether a particular characteristic of the organism associated with advancing age is the cause of general aging or is a result of it. This dilemma is seen, for example, in the earlier emphasis on heat and the body, which led to the assumption that loss of heat was the cause of aging and if heat were replaced, aging would be stopped or reversed. In a similar way because sexual intercourse seems to decline with age, it was thought that stimulating increased sexual activity might fend off the more general effects of aging.

At the beginning of the twentieth century, a number of biologists began to write prolifically about aging. Their underlying theme was the identification of causes of aging or the transformations that occur with age in the human species. The writing of the day was surrounded by a great deal of optimism about the potency of science. No problem appeared to be beyond its understanding and perhaps even the extension of the human life span was potentially under humans' control. There was considerable public interest in prolonging life and even bringing back to life persons who had died.

But serious scholars were becoming more cautious in their expectations that life extension or rejuvenation would be easy or within immediate reach. The Nobel Laureate in physiology, Minot, stated both his optimism and his passion with regard to growing old, which he called senescence.

> We should, indeed, like to have some principle given to us which would retard the rate of senescence and leave us for a longer period the enjoyment of our mature faculties. ... I can venture to suggest to you that in the future deeper insight into these mysteries probably awaits us and there may indeed come a time when we can somewhat regulate these matters. (Minot, 1908: 248)

The views of Minot deeply influenced the earliest American psychologist G. S. Hall (1844–1924), president of Clark University. As a developmental psychologist, Hall is credited with initiating research on adolescence. Near the end of his life, Hall (1922) reviewed much of the available information and the then contemporary thinking about aging in his book *Senescence: the Second Half of Life*. Senescence was a term that he adopted from his reading of biologists of his time. He also included his personal psychological interpretations. "As a psychologist I am convinced that the psychic states of old people have great significance. Senescence, like adolescence, has its own feeling, thought, and will, as well as its own psychology and the regime is important, as well as that of the body. Individual differences here are probably greater than in youth" (Hall, 1922: 100). In this statement Hall anticipated many later psychologists who also pointed to an increase in individual differences that can occur in many traits with advancing age.

In Russia in the 1920s, the Nobel laureate in physiology, Ivan Pavlov (1849–1936), and his colleagues had observed that older animals learn differently and develop conditioned reflexes differently from young animals. They thought that the process of inhibition was more vulnerable to age than was facilitation. This would be reflected in the fact that old habits would be more difficult to eliminate than recent ones. They anticipated somewhat a later development in interpreting the slowness of speed of behavior with advancing age by pointing out that when a nerve process is slowed or delayed, remaining traces of each stimulus overly influence succeeding stimuli.

Pavlov's views about aging were not shared by American researchers. He and his followers believed that the role of the central nervous system (CNS) is important in governing the process of aging of the organism. American physiologists had tended to regard aging of the CNS as resulting from the aging of other organs and the circulatory system rather than its being a primary manifestation of the decline in the regulatory capacity of the CNS itself. More recently the CNS has come to be regarded as an important organ in the aging of primates (*see* Brain and Central Nervous System).

The Beginning of the Modern Period of Gerontology

One of the first laboratories for the systematic study of aging was established in 1928 in the psychology department at Stanford University under the direction of Walter R. Miles (1885–1978); it was supported by the Carnegie Foundation of New York. The motivations behind the establishment of The Stanford Later Maturity Study were many, but an important influence was that in California men over the age of 40 at that time were having difficulties finding work because it was assumed that they were too old. The Stanford laboratory produced about eight doctoral dissertations on various aspects of aging, including such topics as the relations of age to creativity, learning, extinction of learned responses, and motor skills (*see* Creativity; Learning; Motor Control).

In the 1930s new support for the systematic study of aging came through the activities of the Josiah Macy, Jr. Foundation of New York. The Foundation had supported studies of degenerative diseases related to aging, but the director, Dr. Ludwig Kast, believed that degenerative diseases were part of a manifestation of the process of aging. With this in mind he encouraged scholarship and research on aging. The study of aging was encouraged as a parallel to the already vigorous areas of research on childhood growth and development.

E. V. Cowdry, a cytologist at Washington University in St. Louis, was urged by the Macy Foundation to organize the publication of a major integrative volume of the information on aging. He was encouraged to enlarge his initial conception of the book, which dealt primarily with biomedical aspects of aging, to include environmental influences and social, psychological, and psychiatric issues as well. This encouragement led to a subsequent multidisciplinary scientific conference and to the collation of the literature on aging from the various sciences in the pioneering volume *Problems of Ageing*, edited by Cowdry in 1939. (It is of interest that the book uses the English spelling of the word ageing rather than the standard American aging.)

At the time Cowdry's book on aging was published, there was a developing concern about the increased role of chronic diseases as a public health problem. Although earlier, infectious diseases were the major influences on mortality in America, heart disease and cancer were increasing as common causes of death.

The developments in the study of aging that had occurred during the 1930s resulted in the desire to create an organization to promote research on aging.

A guest researcher at the Department of Anatomy at Oxford University, Korenchevsky, visited New York and requested that the Macy Foundation sponsor the organization of a Club for Research on Aging. Similar clubs were being organized in Europe. It was thought that such a club would be an organization where men could discuss and dispute aspects of aging as gentleman scholars and researchers. There was established The Club for Research on Aging in New York, which evolved into a conference series on aging supported by the Macy Foundation both before and after 1940.

By 1940 thinking about aging had become more sophisticated and systematic. Both the Public Health Service and the Josiah Macy, Jr. Foundation regarded the processes of aging as multidisciplinary in character. That emphasis has been continued into the present, although many scientists in the various disciplines find it difficult to adopt a multidisciplinary orientation and to regard aging as a multifactorial process having both genetic and environmental basis. Earlier views of aging frequently adopted the medical model, which held that aging is the product of disease. The current view is that manifestations of aging involve many factors that interact to modulate mortality and morbidity.

In 1941 the United States Public Health Service had organized a conference on mental health aspects of aging. At about the same time the Surgeon General of the U.S. Public Health Service negotiated the establishment of a Section on Aging within the National Institutes of Health. In 1941 Dr. Nathan W. Shock was recruited to head the unit. His efforts to initiate research on aging were delayed by America's entry into World War II, which occurred at the same time the research unit was to begin its work.

Contemporary Gerontology

Shortly after World War II ended in 1945, activities in gerontology began to accelerate. Medicine's increasing interest in the age-associated degenerative diseases, the increase of an older population which portended an older society, and general scientific advances made new methods of study available to students of aging. One of the leaders in the Macy Foundation's efforts to develop research on aging was Lawrence K. Frank. He was one of five sponsors involved with the founding of the Gerontological Society in New York in 1945. About the same time the American Geriatric Society was founded with both organizations publishing journals. These societies have shown continuing development in their membership and in the scope of annual meetings. The International Association of Gerontology was founded shortly thereafter with its first meeting in Liege, Belgium, in 1948 and its second Congress in St. Louis in 1951. The first Pan American Congress of Gerontology was held in Mexico City in 1956. These organized efforts in gerontology stimulated research, teaching, and service.

The publication rate of scientific articles in aging has been growing exponentially. The various constituent sciences and professions are beginning to create their own specialized divisions and they publish their own specialized journals. Also, the professional or applied aspects of aging are growing in significance, and leaders in these fields are encouraging opportunities to exchange ideas about conditions that will benefit the lives of older people more immediately. Interest in the process of aging is being expressed both within the disciplines and between the disciplines.

In many countries, longitudinal studies of aging are being developed that depend upon the collaboration of scientists from many fields. Understanding the aging of organisms requires the collaboration of many disciplines and needs to be accompanied by a complex orientation that will undoubtedly require new and more sophisticated models. Of great importance to the longevity, health, well-being, and quality of life of older persons is the development of increasingly sophisticated theory and research on aging. An interest has already been expressed in the encouragement of such models (*see* Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates; Theories of Aging: Biological).

In universities, research units on aging are now common and special degree programs in gerontology are offered in at the baccalaureate, master's, and doctoral levels. Assisting in the growth of teaching is the availability of specialized volumes on aging that provide not only current research findings but also historical background in special areas. New works on the humanities, religion, and aging show a trend in collaboration not previously seen, suggesting that there has been initiated a new phase of scholarship and human service in the field of aging.

Because of the importance of knowledge and research on aging for the well-being of present and future generations, there seems little doubt that gerontology will remain a high priority in academic and professional settings.

Summary

Gerontology, the study of aging, has roots that extend far back in history. Humankind has apparently always speculated about the duration of life and the nature of death. In many early cultures myths were

created about longevity and death that were passed as legends that explained humankind's mortality. These legends also were presented in religious teachings (e.g., that humankind at one point had immortality but through weakness and sin was reduced to mortal existence).

Gerontology appears to be on an expanding growth course for both scientific and practical reasons. There has been increasing scientific interest in understanding processes of aging from molecular biological processes through behavioral, social, and humanitarian factors. Developing and developed societies show increasingly larger numbers of older persons who have changing interests and needs. Serving older populations brings with it concerns about increasing standards and efficiency based upon scientific knowledge.

Understanding and explaining the processes of aging has proven to be complex. Aging may be one of the most complex topics undertaken for research in the life sciences. Perhaps in reaction to the complexity of the subject, investigators have increasingly studied limited aspects of aging. Thus, recent gerontology has been characterized as having many aspect studies and aspect theories. It may also be said that gerontology is a field that is data rich and theory poor. Aided by developments in statistical modeling and analysis, subsystems of the organism may be characterized in terms of causal complexes or subgroups of intereacting variables. The interrelationships of these aspects or causal complexes may lead to an interaction with the models developed in physics dealing with chaotic processes and events.

The increase in initiation of longitudinal studies of human populations that embrace genetic, behavioral, social, and other influences may lead to a more organismic approach to aging in place of the present aspect specialization. The duration of humankind's life increasingly seems to be placed in an ecological context that embraces explanations arising from species and unique individual genetic background together with influences from behavioral and social processes and physical and social environments. It is foolhardy to predict the precise character of gerontology in the twenty-first century, but it seems highly likely that it will show increasing activity and intellectual and scientific sophistication that will provide the basis for significant advances in humankind's quality of life.

See also: Brain and Central Nervous System; Creativity; Evolution and Comparative Biology; Learning; Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts; Models of Aging: Vertebrates; Motor Control; Theories of Aging: Biological.

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Homeostasis, Homeodynamics and Aging

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Glossary

Allostasis – Stability through change.

Essential Life Span (also called Natural Life Span) – The time required to fulfil the Darwinian purpose of life, namely successful reproduction for the continuation of generations.

Homeodynamics – Concept that the internal milieu of complex biological systems is not permanently fixed, is not at equilibrium, and is a dynamic regulation and interaction among various levels of organization.

Homeostasis – The ability to respond, counteract, and adapt to the external and internal sources of disturbances.

Hormesis – Beneficial effects resulting from the cellular responses to mild repeated stress that challenges and stimulates homeodynamic machinery.

Introduction

All living systems, in contrast to the non-living systems, have the intrinsic ability to respond, counteract, and adapt to the external and internal sources of disturbance. The traditional conceptual model to describe this property is homeostasis, which has dominated biology, physiology, and medicine since the 1930s. However, tremendous advances in our understanding of the processes of biological growth, development, maturation, reproduction, and, finally, aging, senescence, and death have led to the realization that the homeostasis model as an explanation is seriously incomplete. The main reason for the incompleteness of the homeostasis model is its defining principle of stability through constancy, which does not take into account the new themes, such as cybernetics, control theory, catastrophe theory, chaos theory, and information and interaction networks, that comprise and underline the modern biology of complexity.

Since the 1990s, the term homeodynamics, introduced by F. E. Yates in 1994, has been increasingly used – though it has not yet fully succeeded in replacing homeostasis. The concept of homeodynamics accounts for the fact that the internal milieu of complex biological systems is not permanently fixed, is not at equilibrium, and is a dynamic regulation and interaction among various levels of organization.

Almost in parallel with the development of the concept of homeodynamics, the term allostasis, coined and introduced by Peter Sterling and J. Eyer in 1988, has been gaining recognition and use. According to the allostasis model, stability through change is the most realistic situation for living biological systems. The allostasis model also takes into account characteristics such as reciprocal tradeoffs between various cells, tissues, and organs, accommodative sensing and prediction with respect to the severity of a potential stressor, and the final cost of making a response and readjustment to bring about the necessary change. Every act of allostasis adds to the allostatic load in terms of, for example, unrepaired molecular damage, reduced energy deposits, and progressively less efficient or less stable structural and functional components. Aging, senescence, and death are the final manifestations of unsuccessful homeodynamics or failure of allostasis.

Components of the Homeodynamic Machinery

Of the numerous biochemical and physiological pathways and processes operating in cells, tissues, organs, and systems in any organism, the key pathways and processes that can be considered to be quintessential components of the homeodynamic machinery are the following:

1. The multiple pathways of nuclear and mitochondrial DNA repair, including those for maintaining the accuracy of the information transfer from DNA to RNA to proteins and those for the removal of spontaneous lesions in DNA.
2. The processes for sensing and responding to intra- and extracellular stressors, such as heat shock response, hemeoxygenase response, stress hormones, and ionic fluxes.
3. The pathways for protein repair, such as the renaturation of proteins by chaperones, and the enzymic reversal of the oxidization of amino acids.
4. The pathways for the removal and turnover of defective proteins by proteasomes and lysosomes.
5. The antioxidative and enzymic defenses against reactive oxygen species.
6. The processes for the detoxification of harmful chemicals in the diet.

7. The cellular and humoral immune responses against pathogens and parasites, including massive apoptosis (programmed cell death) after the completion of the cellular immune response.
8. The processes of wound healing, blood clotting, and tissue/organ regeneration.

In addition to these main categories of pathways and processes comprising the homeodynamic machinery, some other physiological processes include temperature control, the epigenetic stability of differentiated cells, and fat storage and energy utilization.

Of course, all these processes involve genes whose gene products and their interactions give rise to a homeodynamic space, which is the ultimate determinant of an individual's chance and ability to survive and maintain a healthy state. At present, our knowledge about the number of genes and their variants and their multiple interactions and consequences is too meager to identify, define, and manipulate the homeodynamic machinery in any sensible way. In the case of human beings and other social animals, determining the role of psychosocial factors as integral components of the homeodynamic machinery is one of the biggest challenges.

Homeodynamic Space and Longevity

Why members of different species have different life spans and what determines the life span potential of an organism are challenging evolutionary questions. The natural life span of a species has also been termed essential life span (ELS) by Suresh Rattan, or the warranty period of a species by Bruce Carnes and S. Jay Olshansky. ELS is defined as the time required to fulfill the Darwinian purpose of life, that is, successful reproduction for the continuation of generations. Species undergoing fast maturation and early onset of reproduction with large reproductive potential generally have a short ELS. In contrast, slow maturation, late onset of reproduction, and small reproductive potential of a species is concurrent with its long ELS. For example, the ELS of *Drosophila* is less than 1 week as compared with the ELS of *Homo sapiens* of less than 50 years, even though in protected environments (laboratories and modern societies), a large proportion of populations of both species can and do live for much longer than that.

Since the 1980s, Robin Holliday and Tom Kirkwood have been developing arguments based on the allocation of energy and metabolic resources (EMR) as the determinants of an organism's longevity and survival potential. According to their ideas, available EMR must be divided among three fundamental features of life: (1) basic metabolism, which includes biochemical synthesis, respiration, cell turnover, movement, feeding, digestion, and excretion; (2) reproduction; and (3) maintenance through homeodynamic machinery as described previously.

Whereas basic metabolism is essential for all animals, the extent of investment in reproduction and maintenance can vary between species. This is the trade-off, known as the disposable soma theory of aging, between investment in maintenance and investment in reproduction, which are related inversely. The evolved balance between the two depends on the life history strategy and ecological niche of the species. Several comparative studies have reported positive correlations between life span and the ability to repair DNA, detoxify reactive oxygen molecules, respond to and counteract stress, and replace worn-out cells. In addition, negative correlation has been demonstrated between longevity and the rate of damage accumulation, including mutations, epimutations, macromolecular oxidation, and aggregation of metabolic by-products.

Although the reasons for the longevity differences among the species can be explained by the disposable soma theory, significant differences among individuals within a species are much harder to explain. Genes, milieu (environment), and chance factors are thought to be the determinants of individual life span. Of these factors, some understanding is emerging about genes and their associations with survival and longevity. In human beings, association studies on gene polymorphism and longevity have identified numerous genes that function in a variety of biochemical pathways, such as cytokines, cholesterol metabolism, DNA repair, and heat shock response. Such studies will ultimately lead to the elucidation of the nature and number of genes involved in comprising the homeodynamic space of an individual, which may be the basis for its modulation and intervention.

Aging as the Failure of Homeodynamics

The evolved nature of the homeodynamic machinery, in accordance with the life history traits of different species, sets an intrinsic genetic limit on the ELS as described previously. Therefore, aging is considered as an emergent phenomenon seen primarily in protected environments that allow survival beyond the natural life span in the wild. No real genes for aging (gerontogenes) are thought to exist, and the genes in aging were defined by Suresh Rattan in 1995 as being virtual gerontogenes owing to their indirect effects on aging and longevity.

Based on a large body of descriptive data, gleaned during a period of more than 50 years in the field of biogerontology, Robin Holliday has defined aging as the progressive failure of homeodynamics. Collectively, biogerontological data characterize aging as a progressive accumulation of molecular damage in nucleic acids, proteins, and lipids. Since the occurrence and accumulation of molecular damage are mainly stochastic, aging is manifested differently in different species, in individuals within a species, organs, tissues, cells, and subcellular components within an individual. The main cause of age-related accumulation of molecular damage and its consequences is the inefficiency and failure of maintenance, repair, and turnover pathways that constitute the genetically determined homeodynamic machinery.

A generalized definition of aging as the failure of homeodynamics still requires a mechanistic explanation as to why such a failure occurs in the first place and what controls the rate of failure in different species. Over the last 50 years, researchers have proposed a large number of hypotheses that attempt to explain how the observed age-related changes in macromolecules, cells, tissues, organs, and systems may occur. The main examples of such hypotheses include altered gene regulation, somatic mutation accumulation, protein errors and modifications, reactive oxygen species and free radicals, immune remodeling, and neuroendocrine dysfunctioning. At the cellular level, the so-called telomere loss theory and the epimutation theory of progressive loss of DNA methylation are other examples of mechanistic explanations for the loss of proliferative potential of normal, differentiated, and diploid cells *in vitro* and *in vivo*.

These and other related hypotheses that provide a variety of explanations for understanding the observed age-related alterations at a specific level can be quite useful within their area of focus. However, in order to answer the question of why the occurrence of detrimental and eventually lethal changes cannot be avoided completely, one has to appeal to the evolutionary theories of aging and longevity, as discussed previously.

Several theoretical and mathematical models are being developed in order to understand the interactive nature of the biological networks and trade-offs. Recently, the reliability theory of aging and longevity proposed by Leonard Gavrilov, about the inevitable failure of complex systems such as cells and organisms, has reiterated the principle that no process can be 100% accurate 100% of the time; and it is the interactive nature of genes, milieu, and chance that effectively determines how long homeodynamic ability can keep a biological system alive.

Homeodynamics and Aging Intervention, Prevention, and Therapies

According to the homeodynamics-based explanations for aging and longevity described previously, the bodies that we have developed after millions of years of evolution, the occurrence of aging in the period beyond ELS, and the onset of one or more diseases before eventual death appear to be the normal sequence of events. This viewpoint makes modulation of aging different from the treatment of one or more specific diseases. In the case of a disease, such as a cancer of any specific kind, its therapy will, ideally, mean the removal and elimination of the cancer cells and restoration of the affected organ or tissue to its original, disease-free state. What, then, will be the treatment of aging and to what original age-free stage would one hope to be restored? Considering aging as a disease and then trying to cure that disease is unscientific and misguided. Similarly, although piecemeal replacement of non-functional or half-functional body parts with natural or synthetic parts made of more durable material may provide a temporary solution to the problems of age-related impairments, it does not modulate the underlying aging process as such.

Scientific and rational anti-aging strategies aim to slow down aging, to prevent and/or delay the physiological decline, and to regain lost functional abilities. Strengthening, improving, or enlarging the homeodynamic space at the level of all genes comprising the homeodynamic machinery of an individual may be the ideal anti-aging solution. However, such a gene therapy approach for gerontomodulation requires redesigning the blueprint for structural and functional units of the body at the level of genes, gene products, macromolecular interactions, molecular milieu interactions, and so on. Considering how little information and knowledge we have at present about the interacting variants of genes, molecules, milieu, and chance, it is not clear what this approach means in practical and achievable terms.

Improving the milieu in which the homeodynamic machinery operates is the other strategy that is being followed by most of the so-called anti-aging experts. Some of the main approaches include supplementation with hormones including growth hormone, dehydroepiandrosterone (DHEA), melatonin, and estrogen, and nutritional supplementation with synthetic and natural antioxidants in purified form or in extracts prepared from plant and animal sources. Although certain of these approaches have been shown to have clinical benefit in the treatment of some diseases in the elderly, none really modulate the

aging process itself. Furthermore, claims for the benefits of intake of high doses of vitamins and various antioxidants and their supposed anti-aging and life-prolonging effects have very little scientific evidence to back them.

In contrast, nutritional modulation through caloric restriction (CR) has been shown to be an effective anti-aging and longevity-extending approach in rodents and monkeys, with possible applications to human beings. However, this is a highly debatable issue at present both in terms of the practicalities of defining CR and in terms of applying CR to human beings in physiological and evolutionary contexts.

Homeodynamics and Hormesis as an Aging Modulator

In a more realistic and near-future scenario, a promising approach in aging intervention and prevention is based on making use of an organism's intrinsic homeodynamic property of self-maintenance and repair. Since aging is characterized by a decrease in adaptive abilities due to progressive failure of homeodynamics, it has been hypothesized that if cells and organisms are exposed to brief periods of stress so that their stress response-induced gene expression is upregulated and the related pathways of maintenance and repair are stimulated, one should observe anti-aging and longevity-promoting effects. Such a phenomenon, in which stimulatory responses to low doses of otherwise harmful conditions improve health and enhance life span, is known as hormesis. (Although the term hormesis was coined in the 1930s, its revival and wide use are accredited to Edward Calabrese.)

The phenomenon of hormesis has been defined in various ways depending on the context. For example, in toxicology, pharmacology, and radiation biology, hormesis is defined by non-linear U-shaped or reverse U-shaped dose–response curves. In biogerontology, hormesis is characterized by the beneficial effects resulting from the cellular responses to mild repeated stress that challenges and stimulates homeodynamic machinery. The paradigm of hormesis in aging is moderate exercise, which is well known to have numerous beneficial effects despite or because of it being a generator of free radicals, acids, and other damaging effects.

Mild stresses that have been reported to delay aging and prolong longevity in various systems (for example, yeast, *Drosophila,* nematodes, rodents, and human cells) include temperature shock, irradiation (UV, gamma, and X-rays), heavy metals, pro-oxidants, acetaldehyde, alcohols, hypergravity, exercise, and food restriction. Hormesis-like beneficial effects of chronic but mild undernutrition have been reported for human beings. Intermittent fasting has been reported to have beneficial effects on glucose metabolism and neuronal resistance to injury.

Although at present there are only a few studies performed that utilize mild stress as a modulator of aging and longevity, hormesis can be a useful experimental approach in biogerontology. However, there are several issues that remain to be resolved before mild stress can be used as a tool to modulate aging and prevent the onset of age-related impairments and pathologies by improving the homeodynamic space of an individual. Some of the issues in the applicability of hormesis as a homeodynamic stimulator are the following:

1. establishing biochemical and molecular criteria for determining the hormetic levels of different stresses;
2. identifying differences and similarities in stress response pathways initiated by different stressors;
3. quantifying the extent of various stress responses;
4. determining the interactive and pleiotropic effects of various stress response pathways;
5. adjusting the levels of mild stress for age-related changes in the sensitivity to stress;
6. determining the biological and evolutionary costs of repeated exposure to stress; and
7. determining the biological significance of relatively small hormetic effects, which may or may not have large beneficial effects during the entire life span.

Resolution of these issues requires much more research on hormesis than is being carried out at present. The proof of the hormetic principle has now been provided by experiments with a wide variety of biological systems and by using a range of physical, chemical, and biological stressors. Two of the main lifestyle interventions, exercise and reduced food intake, both of which bring their beneficial and anti-aging effects through hormesis, are being widely recognized and increasingly practiced as an effective means of achieving a healthy old age. In the consideration of irradiation as a hormetic agent, epidemiological studies of the public, medical cohorts, and occupational workers confirm that low doses of radiation are associated with reduced mortality from all causes, decreased cancer mortality, and reduced mutation load observed in aging and cancer. Increasing use of low-dose total body irradiation as an immunotherapy for cancer also has its basis in hormesis. However, in order that this approach could be developed into a safe and preventive strategy against a variety of age-related diseases, certain issues, for example, those related to radiation load

versus mortality curve, bystander effects, and the nature of energetic particles, need to be resolved.

Hormesis through mental challenge and through mind-concentrating meditational techniques may be useful in stimulating inter- and intracellular debris removal processes, thus preventing the neuronal loss that leads to the onset of age-related neurodegenerative diseases. One can also expect the availability of certain nutriceutical and pharmacological hormetic agents to mimic mild stress as a challenge for the homeodynamic machinery. Plant components such as resveratrol, celastrol, and curcumin are among the potential hormetic molecules identified so far.

Recapitulation

Living systems survive by virtue of a set of defensive maintenance and repair systems that comprise their homeodynamic ability. A large number of interacting genes and genetic networks constitute this machinery, the exact details of which are yet to be unraveled. Successful homeodynamics is crucial for the growth, development, and maturation of an organism until the reproduction and continuation of generations are assured. Homeodynamics is thus a longevity assurance mechanism, whose strength, efficiency, and range have evolved in accordance with the evolutionary history of the species. Survival beyond the required essential life span of a species is necessarily accompanied by the progressive accumulation of random molecular damage. The progressive failure of homeodynamics leads to the physiological malfunctioning manifested as a general functional decline, diseases, and ultimate death. Rational strategies to slow down aging or to prevent the onset of age-related frailty and diseases require the stimulating and strengthening of the homeodynamics of individuals.

See also: Life Span Theory; Markers of Aging; Slowing of Aging; Theories of Aging: Biological.

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Hospice

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Glossary

Hospice – A philosophy of caring for dying patients and their families while emphasizing quality of life.

Introduction

Hospice is a philosophy of caring for dying patients and their families while emphasizing quality of life. Care is provided by an interdisciplinary team to meet the patient's and family's needs throughout the dying process as well as after death. Bereavement care is a key component of hospice, setting it apart from other forms of institutional care provided to dying persons. All hospices share certain characteristics that set them apart from other forms of health care for terminally ill persons: (1) the dying person and family

are the unit of care, (2) the interdisciplinary team serves both the dying person and the family, (3) care focuses on the physical, psychosocial, socioeconomic, and spiritual aspects of dying, (4) services are available on a 24 hour a day, 7 days a week basis, (5) inpatient and home care services are available, and (6) bereavement counseling and support (both prior to and after the individual's death) are available to the dying person and/or the family. Many, if not all, of these issues are reflected in dying persons' perceptions of what is important to them at the end of life. Many hospices are dealing with the financial realities of caring for persons whose resources are limited, and are finding themselves thrust into debates about physician-assisted suicide, euthanasia, and end-of-life care.

The Hospice Philosophy

Hospice is a philosophy of care for people who have terminal illnesses as well as for their families, emphasizing the quality over the quantity of life. Via the active involvement of an interdisciplinary team, a coordinated, individualized plan of care is developed for each patient-family unit. The focus of such care is on pain management and symptom control in the context of maintaining quality of life for the dying patient and his or her family. Death in the hospital (or in the nursing home) is often depersonalized and hidden from public view, in contrast to the deaths of persons in hospice, which are more real, human, and meaningful. Rather than viewed as the end of life, deaths in hospice are better thought of as 'spiritual transformations' from this life to the next. This redefined notion of death in hospice is predicated on the basis of the fact that death need not be accompanied by suffering, i.e., that such care is palliative, and that the patient's and family's wishes will be identified and honored. In effect, death and dying in hospice is a natural event, in contrast to dying in an institution. While hospital care has been characterized as 'event oriented' (focused on the prevention of the event of death), hospice care is 'process oriented' – dying is its focus.

The many problems linked to institutional dying are being addressed by societal and professional efforts to humanize dying by defining the rights of dying persons and by making recommendations about how end-of-life care might be improved. Such efforts were stimulated by the failure of project SUPPORT (Study to Understand Prognoses and Preferences for Outcomes and Risks of Treatment), which attempted to enhance the quality of life for dying patients by improving the communication skills of health-care professionals (i.e., physicians).

In North America, five models of hospice care exist: (1) home-based care, often provided by community-based professionals and volunteers (90% of hospice care is provided in patients' homes), (2) home-based care provided by home health-care agencies or Visiting Nurse Associations (VNA), (3) free-standing, full-service, autonomous hospice facilities, (4) separate hospital-based palliative (pain-reducing) care units, and (5) hospital-based subacute units, emphasizing continuum of care. While many do not differentiate hospice care and palliative care, a distinction between the two is increasingly more commonplace, wherein the latter is typically broader than the former.

Some hospices have begun to explore the concept of adult hospice day care, and moreover, pediatric hospice programs are also becoming more common. Approximately half of all hospices are hospital based, while the balance are operated by home health-care agencies. Most (nearly 80%) are nonprofit in nature, while approximately 15% are for-profit. A third are free-standing facilities. Perhaps reflecting the impact of the hospice philosophy or the dissatisfaction with institutionalized care, nursing homes and assisted-living communities are now providing hospice care, underscoring the continuum of care provided to persons who at one time had been in better health. While most hospice patients have cancer (over half of persons who die of cancer receive hospice care), persons being cared for by hospice also die of AIDS, end-stage heart, lung, or renal disease, dementia (e.g., Alzheimer's disease), and cardiovascular illness. While many such hospice patients are older, hospices care for persons of all ages. Some have greater degrees of community support than do others, and while some still operate on a not-for-profit basis, others that are for-profit in nature are often owned by larger corporations. Approximately 25% of all persons who die will have received hospice care, and the vast majority of hospice patients die at home. The average length of time persons receive hospice care is approximately 50 days.

Regardless of the model of hospice care, all hospices share certain characteristics that set them apart from other forms of health care: (1) the dying person and family are the unit of care, (2) the interdisciplinary team serves both the dying person and the family, (3) care focuses on both the physical and psychosocial aspects of dying, (4) services are available on a 24 hour a day, 7 days a week basis, (5) inpatient and home care services are available, and (6) bereavement counseling and support (both prior to and after the individual's death) are available to the dying person and/or the family. Many, if not all of these issues, are reflected in dying persons' perceptions of what is important to them at the end of life.

These characteristics reflect some very basic ideas about life and death: (1) dying is a natural experience; life and death are equally important and meaningful aspects of our existence; (2) dying persons and their families are important in themselves: the dying person's welfare comes first; (3) dying persons should be able to continue to make decisions for themselves until they are unable or unwilling to do so; (4) it is not demeaning to depend on and be cared for by others; and (5) our relationships with those who have died continue to be important influences on our lives.

Reflecting the continued impact on the lives of patients' families after the patients' death, bereavement researchers are now exploring, more broadly, notions of 'a good death,' with an eye to potential effects on bereaved survivors. Attention is focused on such factors as the dying person's acceptance of and peace with death, alleviating pain, the quality of family relationships, place of death (home, hospice, hospital), and the timeliness of the death. More time in the home setting, in particular, is viewed as allowing the family greater opportunities for meaningful communication and the completion of 'unfinished business,' a meaningful trade-off for many with respect to having to endure pain and emotional distress.

The essential one-on-one aspect of the hospice care philosophy has historically stood in contrast to the cure orientation of conventional hospital oncology care or the maintenance mentality of the nursing home. Hospice patients are less likely to receive intensive medical interventions such as chemotherapy or surgery as well as diagnostic tests (blood tests, X-rays) in the weeks prior to death than those in conventional hospital oncology units. Moreover, while analgesics are more likely to be regularly prescribed for pain on a fixed schedule in conventional health care, pain medication is prescribed on an as-needed basis in hospice.

Origins of Hospice Care

The primary stimulus for hospice in the United States came from the St. Christopher's hospice in London, founded by Dr. Cecily Saunders in 1967, though hospices had existed for many years in Europe. Since then, prompted by the opening of a home-based care hospice, Hospice Inc., in New Haven, Connecticut in 1974, nearly 3300 hospices have been founded in North America. Changes in attitudes toward death, legal decisions and legislation affirming the right of the individual to refuse life-sustaining treatment, and the development of the Medicare Hospice Benefit have also encouraged the expansion of hospice in the United States. Other events important to the development of hospice are the founding of the first hospital-based hospice in North America – the palliative care unit at the Royal Victoria Hospital in Montreal – and the formation of the National Hospice Organization (NHO) in 1977 (now known as the National Hospice and Palliative Care Organization [NHPCO]). In 1992, the principal fund-raising arm of the NHPCO, the National Hospice Foundation (NHF) was founded. NHPCO has been effective in educating the public about hospice and in formulating standards for quality hospice care critical for their accreditation, which makes hospice a viable alternative to institutional care for terminally ill persons and their families.

Who Pays for Hospice Care?

Hospice care became a recognized benefit under Medicare in 1983, and approximately 90% of all hospice programs are Medicare certified. As 28% of all Medicare costs go to persons in their last year of life, and 50% of such costs are expended during the last 2 months of life, hospice can indeed be viewed as an alternative to more expensive and lengthy hospitalizations. While there is an upper limit to what Medicare will reimburse, patients cannot legally be discharged from services if their Medicare ceiling has been reached. Typically, assuming this ceiling is not reached, 6 months' worth of care is covered, unless the dying person's prognosis is recertified by the hospice medical director. For low-income persons, hospice services are also qualified under Medicaid in most states.

Studies have shown that while dying persons represented only a small percentage (1%) of all Medicare beneficiaries at any given time, such persons were consuming a disproportionate share of all Medicare expenditures. Thus, 3 years after hospice care was made reimbursable under Medicare, legislation was passed permitting state Medicaid programs the option of covering hospice. The hospice benefit under Medicare requires that core professional services – physician, nursing, counseling, and medical social work services – be directly provided by the hospice. However, it does not require that hospices directly operate home care or inpatient care facilities. Rather, Medicare simply requires that the hospice staff maintain responsibility for all services regardless of their location and that they guarantee access to such services on a 24-hour basis. Hospices receive a specified amount for each day that regular home care is provided to a patient, and all funds paid to the hospice indeed go directly to the hospice program. The same concerns regarding the costs of acute care for dying persons

that convinced Congress to establish a Medicare benefit have prompted private health insurance companies to move toward hospice coverage. Even when covered by Medicare, hospice costs are sometimes unnecessarily paid by patients and families because questions about private health insurance coverage were not asked.

Case Management in Hospice

Case management ensures that quality care is available to, and continuous for, each patient and family. This is especially important because patients and families often know little about caregiving and may have difficulty in dealing with other agencies. The coordination of care within the interdisciplinary team as well as with other professionals outside of hospice is an essential component of the case management mold in hospice. Case management matches each unique patient-family unit with whatever services they may need, as well as monitoring changes in their needs for such services. Case management also helps patients and families arrange for insurance coverage, plan for emergencies, and if necessary, arrange for services from other agencies. In hospice, case management is often carried out by the primary care nurse or by the social worker.

The care plan for the patient and family is implemented with the patient's and family's needs in mind. It is a process that the dying patient and family actively participate in. Information about the patient's needs is often gathered via interactions with patient and family. This information is utilized by the interdisciplinary team in formulating a care plan. The team also arranges to coordinate and deliver hospice services, monitors the effectiveness of these services, and if necessary, reevaluates the care plan if the patient's physical or emotional status changes. Numerous decisions regarding everyday changes in the dying person's energy level, emotional state, functional (decision-making, self-care) skills, and needs for pain medication must be made by the team, yet must be balanced against the quality of the dying person's life as well as against the demands on the family of work, school, raising children, housecleaning, cooking, and bill paying. Additionally, changes in the family's needs for support and information are likely. For example, the patient and family may initially ask about insurance coverage, the nature of the illness, its progression and treatment, or what the family can do to help care for a dying loved one. They may also want to know about the side effects of pain-relieving medications. As the patient's condition worsens, needs for reassurance and support may surface, and concerns about planning a funeral, writing a will, or living without a loved one may be shared. When their loved one is near death, the family may be less verbal about their needs, and emotional support from a staff member or volunteer may be all that they require. Rather than 'doing something,' hospice personnel may meet this need by simply 'being there.' Indeed, perhaps the greatest lesson that hospice teaches us is that persons can grow spiritually and emotionally by being with a loved one at a very sad and emotionally difficult time of life. Hospice staff and volunteers simply do what they can to make this growth possible.

Legal and Ethical Aspects of Hospice Care

NHCPO does not support either suicide or euthanasia in hospice; indeed, they are infrequent among hospice patients. However, there is the occasional individual for whom 'rational' suicide and/or euthanasia may be perceived as an alternative to living in pain or dying an undignified death. While such statements may mean that the patient's needs are not being met by the hospice, they may also reflect family difficulties, resulting in the dying person's feeling rejected and unloved. Suicidal thoughts may be shared openly or may be unexpressed. Such persons may have a hard time sleeping or eating, refuse medications or visitors, or suddenly change a will.

A wish to commit suicide may also reflect an individual's particular moral values about the quality versus quantity of life. If such concerns do surface, the caregiver should explore whether they are shared by family members, and if they are not, or if the family are unaware of them, the caregiver must make a choice regarding whether to discuss these concerns with the family. In most cases, however, it is preferable that the patient's wishes to discuss suicide or euthanasia with his or her family be respected. Many hospices have adopted a policy against active euthanasia, and feel the same way regarding the acceptability of suicide. What death and dying mean to each person should be explored so that the dying patients can understand and clarify their feelings as to why suicide or euthanasia might be preferable to living, and so that the caregiver can more fully understand the dying person. Not discussing such topics or making them seem unimportant suggests communication difficulties that must be remedied quickly.

The Interdisciplinary Team

Hospice uses an interdisciplinary team to tend to the well-being of dying persons and their families, and

have been demonstrated to be effective in this respect. The term interdisciplinary reflects the variety of skills that professionals, paraprofessionals, and volunteers all contribute in meeting the complex and changing physical, psychosocial, and spiritual needs of the patient and family. In this regard, the team functions to ensure that the dying patient and family function as well as possible given the burden of facing a terminal illness and the realities of daily life: maintaining a household, holding a job, and raising children. The patient's medical needs are given priority, but the patient's and family's needs for intimacy, privacy, and support from relatives, friends, or neighbors must also be met. As the essential component of hospice, the team functions to evaluate and meet the special requirements of each patient-family unit. Within the plan of care that has been developed for the patient and family, the patient care coordinator, who is often the social worker or nurse, brings together each member of the team to assure continuity of care. Not only is this vitally important during the period of time the patient is actually receiving hospice services, but it is also essential to providing effective bereavement support. Such support is especially critical if the staff sense that the family wishes to disengage from them after the death.

Ideally, the team is composed of persons with a mix of professional expertise and background, i.e., nurses, social workers, clergy, physicians, counselors/psychologists, dietitians, physical therapists, pharmacists, and volunteers. For the most part, direct patient hospice care is managed and carried out by nurses in either inpatient or outpatient settings, under the direction of the hospice medical director in concert with the patient's physician. Important roles are also played by clergy, social workers, and especially volunteers. In most cases, teams meet on a weekly or semi-weekly basis to review each case and to discuss problems encountered in carrying out the plan of care, as well as to discuss problems within the patient-family unit itself. As noted previously, the care plan may need to be modified for any number of reasons.

Physicians have direct input into the delivery of care and are primarily responsible for the direction of the medical care that encompasses ongoing, daily, and emergency care. Physicians formulate a medical regimen of pain and symptom control using an array of narcotic and non-narcotic analgesics (pain-relieving drugs). In hospice, however, the physician's role is best defined in the context of the entire team, and likely varies a great deal from hospice to hospice. In rare cases, the role of the physician may be minimal, and the physician may not actively function as the medical director or as a participating member of the team. Relative to the more traditional physician, hospice physicians are more likely to play a less authoritarian role in the delivery of care. They are more patient-family oriented and more strongly emphasize clear, effective, and empathic communication with both patient and family as well as with other hospice staff. Perhaps the physician's most important role, other than in prescribing pain medication, is to serve as a liaison between the hospice and physicians in the community as well as with the patient's personal physician, from whom referrals often originate, and whose attitudes about hospice are critical.

Nurses in hospice often make an initial assessment visit with the family and, because they see the dying person most often, frequently oversee the coordination of direct patient care among the team. In an initial visit, the nurse learns about the history of the illness from the point of view of both the dying person and the family and assesses their needs to help the hospice care team to design a care plan. The nurse is equally attentive to the emotional needs and physical well-being of the patient and family. Relieving pain promptly, as pain often but not always accompanies a terminal illness, as well as keeping the patient as pain-free as possible, is vitally important. Listening and 'normalizing' everyday life are also very important aspects of the role that the hospice nurse plays.

While nurses often provide most of the direct, hands-on skilled care, the social worker may also serve as a case manager. The social worker often conducts the initial psychosocial assessment of the patient-family unit, dealing with such issues as insurance coverage, pensions, wills, and funeral planning. While medical social workers may function similarly to the nurse regarding the family's well-being, they usually assume primary responsibility for tending to the financial and/or legal aspects of terminal care with the family and in helping the family obtain outside assistance with home care, meal planning, or meeting transportation needs. The social worker also often oversees the follow-up bereavement care of the family. In many hospices, a social worker's importance to the welfare of the dying patient and his or her family rivals that of the nurse.

Most hospices could not exist without a viable force of volunteers. The roles of many volunteers are extensions of their professional lives, while those of others are not. Some tend to clerical work, while others work more directly with patients and families. The volunteer can assist the patient and family in a variety of ways on either a continuing or an as-needed basis. Volunteers can, by simply listening and observing, monitor the family's physical and emotional status so that a crisis of caregiving can be

avoided. Volunteers can also help in the provision of care itself: turning patients in bed, providing personal grooming and hygiene assistance, helping with household chores, picking up children from school, or, most importantly, simply being present. Volunteers are an absolutely essential component of the hospice team and should function as such. In most hospices, a volunteer coordinator helps match and assign volunteers to patients and families, and may assist in coordinating and delivering volunteer training. By accompanying the nurse or social worker on an initial visit, the volunteer coordinator can learn about each family's background, interests, and unique needs that influence hospice care, as well as form an impression of each family member as a person.

The role of the clergy is usually more subtle. The clergy often function only on an on-demand basis in hospice, though it is difficult to generalize about the extent of their involvement. Clergy are involved in the team to shed light on the spiritual needs of the patient and, if the patient has no religious affiliation, to minister to the patient and family. Rather than promoting a particular religious philosophy, the chaplain sees to the patient's spiritual well-being by being a link to the religious community. The chaplain often assists in bereavement follow-up as well as in the training of volunteers. The chaplain can also function as counselor, listener, problem-solver, mediator, or friend, as can the hospice administrator, depending on his or her training, over and above the overseeing of personnel and reimbursement issues within the hospice.

Few hospices actually have a psychologist as a paid staff member or a volunteer, though this is changing as the patient-family unit's emotional well-being is being recognized as an even more important influence on the health of the dying person and his or her family. The role of the psychologist or counselor is key in that hospice staff spend more time offering counseling to patients and families than any other activity other than providing direct nursing care. The psychologist or counselor, for the most part, plays a supportive role in consulting with the team regarding the psychosocial functioning of the patient or family. The expertise of counselors or psychologists may be sought regarding family conflicts associated with the stress of terminal care, or long-standing difficulties that are brought to the surface via the dying of a family member. Such conflicts often interfere with either the delivery of care or the patient's or caregiver's well-being. Counselors and psychologists can also help hospice staff cope with the physical, emotional, and even the spiritual demands of their work.

Burnout and Attrition in Hospice

Stress among hospice workers is unique in that uncertainty about whether one's efforts are effective, the duration of time spent with patients, and the importance attached to one's work are all high. Working with dying patients and their families ensures that the staff will have to cope with the deaths of persons to whom they have grown quite close. This, for some persons, takes an enormous emotional toll. While individuals vary in their ability to appraise and respond to stress, the unique commitment hospice staff have to their work and the demanding nature of working with dying persons make them especially prone to stress and burnout. Most hospices now recognize that some form of regular, timely staff support is critical for lessening stress and minimizing staff turnover, though this has not always been so. Staff with little family support who work in home-care-based hospice situations seem to be at greater risk for job stress and burnout. Younger or less mature caregivers also seem to be more prone to dysfunctional stress reactions due to a lack of emotional preparation, as do persons who are more anxious about death or who are trying to cope with the loss of a loved one by immersing themselves in hospice.

Given that burnout predicts the long-term attrition of hospice staff, perhaps most important in minimizing burnout is the selection of hospice staff. Excluding persons who have experienced recent personal losses as well as those with a great deal of anxiety or concern about their own deaths or about being around dying persons is important. Over and above the issue of selection of team members, the team members must have time to be alone with one another to discuss technical and creative issues, as well as to express their feelings and provide emotional support to each other regarding their work. Taking care of oneself is central to lessening hospice team stress and burnout. Moreover, opportunities for continued training and cross-disciplinary sharing outside of hospice are essential for minimizing attrition.

Patient-Family Dynamics in Hospice

While the needs of the dying person are an important focus of hospice, that person is embedded in a matrix of relationships and interactions with other family members. Death may disrupt patterns of communication, role responsibilities, decision making, and assertions of power or dominance within the family. The very identity of the family and of the individuals in that family may be threatened by death. Each family's reaction to the diagnosis of a terminal illness, its management of a loved one's dying, and its

postdeath functioning are all determined by previous family styles and patterns of coping. The impact of death also varies according to whether a parent or a child dies, and with what stage of the family life cycle the family is in.

When hospice care is provided by the family at home, caring for a dying loved one can present an additional burden the family may see as impossible to cope with. The family must believe that home care is both possible and desirable, and they must have access to professional assistance as well as specialized equipment that is often essential to quality terminal care. The family must also have the nursing skills to make physical care possible. Moreover, knowing when death is imminent, what to do at the moment of death, and what to do immediately after death are important skills and knowledge that are important factors in choosing home care. Families report that changes in the dying person's mental status (inability to communicate, confusion, seizures) and changes in his or her ability to care for him- or herself are the most troublesome, as are administering medications and dealing with the loss of bladder or bowel control. Putting personal and career goals on hold, having little 'alone time,' being isolated from others, feeling guilty, and neglecting one's own health are also sources of stress among caregiving families.

Findings suggest that families who have a loved one dying of AIDS face even greater difficulties. Such families express more difficulty in sharing their feelings, report more stress, are less trusting, and have more illness anxiety than families coping with other terminal illnesses. Hospice staff can help in the performance of many needed tasks through education of the family and through the provision of psychological and spiritual support. In most cases, details that seem unmanageable, horrid, or repulsive become less so with a bit of 'hands-on' teaching and knowledge. Because hospice care extends beyond the death of the patient, it is also important to observe how both the patient and family deal with their grief, as this influences the postdeath adjustment of the survivors. Opening up lines of communication may help families face the reality of a loved one's death, particularly if they have had little recent contact with the dying person or if there are long-standing family difficulties.

In evaluating the patient-family unit, the focus is likely to be on the woman's well-being, health, and extent of social support from others, as female spouses tend to experience more family caregiver burden than both men and children. Indeed, psychosocial and emotional support given to the primary caregivers by family is critical. It is also helpful to explore the extent to which family caregivers are depressed, whether they have used social services in the past, and their explanations for the dying person's behavior, as these factors have also been found to predict caregiver burden and may constitute adjustment difficulties in themselves. Such insight may require several visits to achieve, and may necessitate an assessment by more than one hospice staff member. An evaluation of the family's support system is also critical to understanding how they will cope with the illness – do they have extended family, friends, neighbors, or co-workers available? What local support agencies have they contacted (e.g., nursing home, home health-care services)? Do they have savings or private insurance? How much of the cost of care is Medicare likely to cover? Has a will been written? Have funeral arrangements been made? Do they attend or are they members of a church? Would a visit from the hospice clergy be helpful? Through all of this, the family should sense this active support and interest in their welfare and functioning by hospice staff. In cases in which significant family dysfunctional patterns are interfering with care, more formal family therapeutic interventions may be necessary.

Grief and Bereavement in Hospice Care

Bereavement follow-up is a primary characteristic of hospice, and it sets hospice apart from other types of health care for dying persons and their families. In many respects, the job of the formal caregiver has just begun when the patient dies. The family must be sustained and cared for well beyond the death of a loved one, and bereavement care facilitates the expression of grief before death and thereby lessens its severity after death. The same personnel are encouraged to stay in contact with the family to ensure continuity of care. Different staff, however, may be involved to encourage the family to develop new relationships.

The major objectives of hospice bereavement care are for the family to (1) accept the reality of the loss of a loved one, (2) experience the pain of grief, (3) adjust to an environment without the deceased family member, and (4) re-invest energy into other relationships. Research from the National Hospice Study suggests that while hospice bereavement programs can be very beneficial, objective evidence supporting their efficacy is sparse, though the odds of a surviving spouse dying within 18 months of his or her spouse's death are greater if hospice is not used. In addition, better postdeath adjustment has been found among spousal survivors who used hospice.

Bereavement care is often carried out by social workers, nurses, or volunteers. Bereavement care

often focuses on those whose grief is pathological, or on those persons who might have later difficulties in coping. A variety of diverse bereavement services are offered by hospices, including attending the funeral, providing individual or group counseling, sending postcards, making telephone calls, and holding memorial services and other social events. The intensity of involvement by individual hospice staff or by the interdisciplinary team varies, as does the formality of objective bereavement follow-up. Counseling, companionship, and assessment are the prime reasons reported by staff for bereavement visits, and persons in home-based hospices typically receive more bereavement support and counseling than those in hospital-based hospices.

Related to such bereavement support is the fact that persons in home-based hospices are more emotionally distressed and experience more caregiver burden prior to death than those in hospital-based hospices. Because hospice care places a special burden on those family caring for a loved one at home, individuals who have suffered more due to the demands of caregiving may fare more poorly after death. Those survivors who experience greater caregiver burden before the death also experience higher levels of depression and more problems with self-care. After the death, however, their symptoms appear to decline to the levels of non-burdened caregivers. This may reflect a sense of relief as the patient's suffering comes to an end. It may also indicate that during a stressful period of caregiving, family and social support networks would have had sufficient time to prepare to be helpful to bereaved persons. It may also indicate that the consequences of caregiving and bereavement are not additive. Indeed, for many persons, a successful experience with the process and responsibility for caregiving might be expected to result in the development of new coping skills and a sense of mastery and accomplishment.

In home-based hospice settings, especially, caregivers may be at risk for trauma, in addition to caregiver burden. They are required during hands-on caregiving (e.g., for a late-stage cancer patient) to witness a family member in severe distress, which may involve intense pain, choking, vomiting, inability to eat, dehydration, confusion, falling, and so on. The intensity of these experiences with a loved one makes it more likely that the caregiver will experience symptom levels associated with major depression and complicated grief (which reflects a trauma component).

Research evidence, however, is mixed regarding the efficacy of counseling interventions for bereavement (informal or professional). The majority of bereavements tend to be relatively uncomplicated with respect to impact on survivors, and in this context, most individuals are able to adapt and to come to terms with their loss without formal intervention. For these persons, emotional and physical distress abates with time, and they are able to access natural support resources from among family and friends or through their religious affiliations. While social support received prior to the death appears not to buffer against consequences of the loss, support from others received after the death may be associated with lower distress.

While formal interventions have not generally been found to be effective in a preventive sense for uncomplicated bereavements, they do appear useful for individuals at increased risk or for those who may be suffering symptoms of especially high intensity or duration. A related concern is that in providing formal outreach services to bereaved persons, hospice personnel may inadvertently discourage family and informal support efforts. Consequently, it is important to understand bereaved family members as individuals, who may or may not want or need the bereavement support that hospice staff may provide. Moreover, theoretical developments in our understanding of grief may render stage-based approaches to bereavement adjustment less meaningful, in contrast to an approach that stresses the individualized and often unpredictable nature of grief. This revised notion of grief suggests that hospice staff may need to be ever vigilant of problems in everyday functioning or emotional adjustment to loss that bereaved persons may experience, irrespective of time or their apparent risk in experiencing such difficulties.

Emerging Issues in Hospice Care

Hospice is in a sense a movement. Its driving influences are spiritual, social, and political, as well as medical in nature. It has grown quickly in many countries, and in the United States, service providers represent several types of entities, within an evolving regulatory environment. In spite of its growth, and the perception that hospice represents a more commonly seen alternative to institutional death, there have been reports of problems with some hospice agencies, and an active consumer advocacy movement has emerged in response to such concerns. It is our sense that a majority of providers, and the major national hospice associations are responsible, compassionate, and competent. That said, it is prudent for patients and their families to explore the consumer advocacy issues raised by their predecessors.

Driven by the increasing numbers of persons who are suffering from AIDS or Alzheimer's disease, hospice staff are likely to become more involved with

medical professionals and specialists (e.g., geriatric psychiatrists, social workers) who may come to function informally as a member of the interdisciplinary team even before the patient enters hospice care. Such involvement is also likely to alter the training that many types of health professionals receive in light of hospice as a viable alternative to institutional care. Likewise, given the attention to issues surrounding end-of-life care (e.g., the use of advanced directives), discussion of numerous moral and ethical dilemmas is likely to be more commonplace among hospice staff. Hospice will also likely need to become more common in rural areas and more available to those dying in prisons, and the unique nature of providing culturally sensitive care to persons of differing races and ethnicities will likely need to be stressed to a greater extent in the future. In addition, greater attention to enrolling patients earlier may be a key element in maintaining quality of life for them, as well as alleviating the depression that often accompanies a terminal illness. Whether hospices are willing or able to admit patients who will not forego hospitalization and who are receiving parenteral nutrition, tube feedings, radiation, or chemotherapy is also emerging as a controversial issue in hospice admission policy. Cost-effectiveness and other forms of accountability (e.g., improved psychosocial and physical functioning in bereavement, documenting increases in quality of life or pain reduction at the end of life, greater attention to the retention and welfare of hospice staff) are also likely to emerge as salient issues confronting many hospices in the future as alternatives to hospice care emerge.

See also: Bereavement and Loss; Caregiving and Caring; Death and Dying; Health Care and Services; Medicare and Medicaid and Economic Policy of Health Care; Religion and Spirituality.

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Housing

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Glossary

Aging in Place – The desire and tendency of older persons to stay in their current dwelling units for as long as possible.

Assisted Living – A residential setting, usually licensed, that provides private apartments (often efficiencies), a full range of supportive services (e.g., meals, personal care), social activities, and continuous protective oversight (24-hour on-site supervision).

Congregate Housing – Semi-independent multi-unit living arrangement that generally provides group meals to residents.

Continuum of Housing – A range of housing options that are differentiated by their complement of services, physically supportive features, and the age or competency level to which they are targeted.

Elder-Friendly Communities – Supportive and accessible communities with design features such as safe sidewalks and legible signs to maintain older adults' independence and access to transportation and services.

Environmental Press – The demands that environmental settings make on residents' physical and mental competencies.

Home Modifications – Adaptations to home environments intended to make it easier and safer for functionally impaired individuals to carry out activities such as bathing, cooking, walking, navigating steps, and opening doors.

Household – A group of individuals or an individual who lives in a dwelling unit.

Naturally Occurring Retirement Communities (NORCs) – Housing complexes or neighborhoods that were not planned for the elderly but that, due to aging in place and in-movement of new elderly residents, contain high concentrations of older persons.

Supportive Housing – Housing complexes in which the owner or manager coordinates a range of supportive services, many of which are provided by third parties, for residents who typically live in their own apartment units. Most do not provide continuous protective oversight and are unlicensed.

Universal Design – A concept promoting homes and communities that are accessible, adaptable, and usable to the greatest extent possible by persons of all ages and abilities.

Visitability – A small set of key accessibility features that enable persons with disabilities to access the main level of single-family homes.

Introduction

The vast majority of older persons live independently in single-family homes or apartments; the importance of their housing extends far beyond the shelter provided by bricks and mortar. The home is the primary base for daily living, and it can represent a lifetime of memories and provide a sense of security for the future. For older homeowners, it is usually their most valuable asset. For older renters on a limited and fixed income, housing is often their largest monthly expenditure. The features of the neighborhood in which housing is located are crucial to community life and accessibility of shopping, social services, medical care, leisure activities, and recreation.

Especially over recent decades, housing for older persons has been viewed as involving much more than conventional shelter. A larger number of people are reaching advanced ages during which they are likely to have chronic diseases, become frail, and experience losses of family and friends. For these vulnerable individuals, housing and related services can be critical to quality of life. They often are the key factor in enabling a frail older person to stay in a residential setting rather than move to a nursing home.

This overview of housing for older people discusses key concepts, perspectives, living arrangements, and the relationship among household tenure, income, and wealth. It also discusses housing types and problems, followed by an analysis of housing policies and programs that have been developed to improve the housing situation of older persons. Although the major focus of this article is the United States, it includes references to experiences in other industrialized countries. It covers the features of housing for older people living in general housing, supportive housing, and links between housing and services. Unless otherwise mentioned, older people refers to those aged 65 years or over.

Perspectives

Housing and gerontology are multidisciplinary fields that draw on a variety of conceptual perspectives. This section reviews three of the main paradigms that have been applied to developing the present knowledge base about housing the elderly: environmental psychology, the housing market approach, and the political analysis of policies and programs.

A major influence on the field of elderly housing has been environmental psychology. Environmental press, the central concept, refers to the match between individuals' functional capacities and the demands of their environments. A good environmental fit will stimulate and support an individual and enhance his or her functioning and well-being. An overly supportive environment can atrophy an individual's capacities, whereas an overly stressful environment risks a breakdown of capacities and distress. As individuals grow older and their needs and capabilities change, it is important to adapt existing environments or ensure appropriate moves to new environments.

The environmental psychology approach is often termed a microperspective because it emphasizes how individuals relate to their residential environments. Starting in the 1960s, the public and private sectors sponsored research that has applied the microperspective to a wide range of important topics. The emphasis has been on how vulnerable older people adapt to specially built accommodations, such as homes for the elderly, public housing, and nursing homes. This research has shown that sensitive and careful design of building layouts, pedestrian walkways, and other features can assist older persons who would have difficulty in conventional housing settings. Until recently, the microtradition has devoted little attention to housing for the majority of older people who are capable and live in single-family houses and neighborhoods.

Since the 1980s, increasing attention has been directed to older persons in the broader housing market. Sociological analyses have focused on the household characteristics of the elderly, whereas economics analyses have focused on their housing characteristics. This macro work has been greatly stimulated by improved census and survey data on the housing types, conditions, and costs for people of all ages. The information reflects increasing policy attention to identifying the needs of special groups in the housing market and maintaining the quality and best use of housing resources. The available data provide a picture of the housing of various age groups and the housing of older people by their race, martial status, income, and location.

An understanding is emerging of how the processes of individual and population aging relate to the changing composition and use of the housing stock. The concept of the life span has been applied to studying housing careers, that is, the succession of dwellings occupied over a lifetime and how these careers interweave with employment and family careers. Housing demography has provided analytical tools that show how the supply and use of housing changes in periods of history, on aging of individuals and cohorts, and with the succession of new cohorts, people, and dwellings. Change in people's use of housing occurs as a result of complex markets for housing, land, and labor as well as public regulations and subsidies.

A final perspective concerns the politics of public intervention in housing markets and the impacts of housing programs. The political economy perspective emphasizes how government policies toward housing are influenced by interest groups, ideological struggles, and economic considerations. Many actions of government – such as subsidies and tax concessions for home ownership – are not age specific but can have significant impacts when people reach old age. Age-specific policies have risen out of concern for the special needs of older persons, a perception of older persons as the deserving poor, and the growth of older people and the industries that serve them as political constituencies. The political agendas of governments also influence the funding of housing evaluations and studies, which in turn shape the availability of information and assessments of program and policy effectiveness. In addition, as housing encompasses more than shelter, it inevitably has to cross agency boundaries and must confront sometimes conflicting goals, guidelines, and methods of operation.

Before turning to the present knowledge base, it needs to be acknowledged that research on aging and housing requires more development. The complex processes of individual and historical change in housing patterns stand in sharp contrast with available evidence based mainly on cross-sectional surveys and aggregated analyses of trends. It is difficult to compare studies because they can apply different definitions of even basic terms such as households, dwellings, and housing types. Findings differ significantly depending on units of analysis, for example, between individuals and households. Even more problematic are cross-cultural comparisons. Conceptual advances will depend heavily on designing better investigations that take more account of the complexity of the field.

Living Arrangements

A household, the basic unit of housing demand, is made up of an individual who lives alone or a group of people who live together. The composition of households has a major bearing on individuals' cost of living, responsibility for household duties, and proximity of social support. Relatively few older people move immediately after retirement, widowhood, or the onset of disability. The vast majority of them experience personal or household changes while remaining in the established home. Although some older people choose to move to more appropriate housing, most prefer to make housing adjustments through aging in place.

In the United States in the late 1990s, 90% of older people lived in conventional housing, consisting primarily of single-family houses and apartments. Approximately 5% of older persons at any one time live in nursing homes, and another 5% live in other forms of housing that have congregate facilities or services, such as meals. The proportion of older individuals in special housing rises with advancing age, yet represents only slightly more than 25% even for those aged 85 years and older. Those who are most likely to live in government-assisted housing are poor, frail, and not presently married. Overall, the proportion of older persons in non-private housing (not in a private household) in the United States has remained relatively stable over the last few decades. These figures are broadly comparable to those of Australia, the United Kingdom, and other Western countries at similar levels of economic development.

Over the post-World War II era, older people have become much more likely to live alone or live only with their spouse. The explanations are rising real incomes, programs of Social Security, relief of housing shortages, and continuing preference for independent living. At present, approximately half of older Americans live only with their spouse, a third live alone, and the remainder live with others (mainly relatives). Living with someone other than a spouse is much more common among older people who are Black, Hispanic, poor, or disabled. Many of the most vulnerable older people, in terms of income and functional capacities, are overwhelmingly widows who only over recent decades have lived in separate households.

As a result of their generally small households, older people have a disproportionately large presence in the housing stock. Approximately 40% of all American dwellings are headed by a person aged 55 years or older. The head of household is the person who holds the title for an owner-occupied home or who signs the lease for a rented dwelling. The household head is the most common unit for housing analyses relating the characteristic of a dwelling to the personal characteristics of the occupants.

A small proportion of the elderly population can be considered homeless. Homeless people by definition do not live in households, and they are virtually invisible in available databases and the housing literature. Other older persons, unable to afford their own homes, live with relatives, unrelated individuals, or in single rooms. The few studies available on these groups highlight their intense difficulties, which can result from a lifelong combination of personal problems and social and economic exclusion.

Housing Tenure, Income, and Wealth

Housing tenure is one of the most significant economic divides among people in old age. If the entry

costs to home ownership can be met earlier in adult life, savings from the years of peak income are likely to be stored in the home, and this wealth increases through appreciation of house prices. In old age, outright home ownership can provide security of occupancy, relatively low cash outlays for shelter, the means to buy into other accommodations, and even a source of cash through programs such as reverse mortgages. Government-subsidized tenants have fewer financial advantages, usually in the form of low rent. Private tenants (in the absence of government protection) face rising market rents and have little security of occupancy.

Older Americans have largely been successful in achieving home ownership. More than eight in ten adults aged 45 and older own their homes. While the rate of homeownership decreases with advanced age, the majority (78%) of older adults over age 75 still own their own home. Only 5% of older Americans receive direct housing assistance from the federal government. Those who rent in old age overwhelmingly live in non-subsidized housing, and they generally have faced lifelong economic disadvantages that restricted capacities to ever buy homes. Permanent tenants include disproportionately large numbers of Blacks, Hispanics, residents of large cities, and people who have never married or had divorced (especially women). The vast majority of older Americans with middle or higher incomes are homeowners, whereas a small minority of those with low incomes are owners.

People who are now in old age have had relatively high lifelong access to home ownership. Those born since the 1920s, who reached old age since the 1980s, were in their prime home-buying years during the economic and housing boom of the 1950s and 1960s. They were assisted by subsidized and regulated housing finance and income tax concessions on interest payments and capital gains. Housing trajectories set during the affluent postwar era are leading to continuing high rates of home ownership for people entering old age during the early years of the twenty-first century.

People who enter old age as homeowners generally remain so for the remainder of their lives. The relatively small numbers who move out of home ownership for the most part are very old widows who are likely to have experienced economic or health-related functional difficulties. This pattern of stability suggests that age differences found in housing markets at any time reflect strong cohort effects as well as aging effects. It also suggests that housing adjustments in old age (when they take place at all) usually occur in the last several years of life.

Owning a home outright is very important in enabling older people to maintain an adequate standard of living on a retirement income. Older renters, however, generally live near poverty levels and are three times more likely to have severe housing costs. Fifty-seven percent of all renters have moderately to severely high housing costs. In comparison, approximately 25% of all older homeowners spend more than a quarter of their income on housing. Excessive housing costs, according to the definition set by the federal government (over 30% of income), are highly concentrated among older persons with low incomes, especially older women and minorities. Such costs make it difficult for older persons to afford other necessities of life such as health care and transportation.

With rising real costs of buying over recent decades, lifelong access to home ownership is likely to be reduced for those reaching old age during the next century. There is likely to be a historic watershed in which fewer older people will have outright home ownership to cushion the effects of low retirement incomes. To sharpen the social divides further, the present cohort of older owners will be bequeathing their housing assets to adult children who also are likely to be owners and who will themselves be on the verge of old age.

The housing tenure of older people and its distributional consequences varies considerably among countries. Although Australia has ownership rates comparable to those in the United States, more people live in public housing in old age and more private tenants have rent assistance. In Britain, only half of older people are homeowners, with 40% in public housing and most of the remainder in protected private tenancies. The distributional consequences of housing have followed very different patterns in European and Scandinavian countries that encourage non-profit housing cooperatives and have fewer policies subsidizing entry to home ownership.

Housing Types and Problems

The vast majority of people enter old age living in homes selected for their appropriateness in midlife when they were in the paid workforce and typically had larger households. For the cohort of people aged 60–69 years in 1960, there were extremely low increases of apartment living over the following 20 years (virtually none among owners and from 11 to 16% among tenants). Thus, with the boom in building detached dwellings in the 1950s and 1960s, four out of every five older people now live in some form of single-family housing. They are no more

likely than younger people to live in apartments or medium-density housing.

The residential stability of older persons, combined with declining household size, has raised concerns about the underutilization of housing resources. In fact, some analysts contend that over 5 million older American households are overhoused because they live in dwelling units in which bedrooms outnumber household members by more than one. However, studies suggest that very few older people consider their homes too large for them. They report making extensive use of spare rooms for family visits, leisure, and other lifestyle activities centered on the home. Moreover, if older people own their homes outright, there is relatively little financial pressure to change housing. The available evidence suggests that older people are unlikely to be induced into smaller dwellings unless financial and other barriers are lessened and attractive alternatives are available in nearby areas.

The condition of housing occupied by older persons has improved substantially over the last several decades. Fewer than 1% of older people live in overcrowded housing, defined as households with more than one person per room. Almost all older persons now live in housing with hot and cold running water, private bathing and toilet facilities, and a sound physical structure. However, nearly 1.5 million older American households live in substandard housing that is in severe need of physical repairs related to inadequately functioning housing systems such as plumbing and heating. As with high housing cost, these problems are highly concentrated among older persons with low incomes, especially older women and minorities. Overall, the extent of housing problems by these measures is roughly comparable among younger and older Americans.

These summary statistics on housing problems require careful consideration. On the one hand, many older people, especially those with functional limitations, have difficulties in the use of their dwelling units even when they are in good condition. The consequences of housing problems can fall particularly severely on a frail older person who is right on the edge of maintaining functional competency. The apparently small percentage (i.e., 8%) living in substandard dwellings still amounts to a very large number of people (more than 1 million).

On the other hand, the majority of older persons are satisfied with their housing, even when it is technically substandard by the preceding measures. They are unlikely to rate housing as a major area of hardship – certainly less so than younger people. These paradoxes may arise because perceptions are highly specific to individual interpretation. In the case of disadvantaged older persons, apparent satisfaction can reflect low expectations that anything can be done to improve their situation.

A long-standing assumption in the field of housing has been that as persons become more frail, they will have to move from one housing setting to another. While many frail older people eventually move to more supportive accommodations, most wish to continue at home for some time. Of the many needs of frail older people at home, the most common are assistance with gardening, home repairs, home modifications (e.g., addition of grab bars, ramps), and transportation.

The idea of a continuum in the supportiveness of housing is important because it recognizes that housing options can be differentiated by the amount and type of services offered; the supportiveness of the physical setting in terms of accessibility, features, and design; and the age-competency level to which the housing setting is targeted. **Figure 1** indicates how different housing options, including single-family housing, apartments, board and care homes, and skilled nursing homes, generally meet the needs of older persons who are categorized as independent, semidependent, and dependent, respectively. Although semidependent and even dependent older persons can be found throughout the continuum, independent older persons are very unlikely to be found in housing types such as assisted living specially designed and equipped for frail older persons. Nevertheless, frail older persons can be found across the housing spectrum, indicating considerable elasticity of different housing types to support them.

Some housing types serve specific subgroups of the population. For example, several types of purpose-built housing for semi-independent older persons have evolved over the last decade. These options are variously referred to in the United States by such labels as board and care, residential care facilities, and assisted living. In Australia, similar types of housing are called hostels; the Scandinavian versions are generally known as service houses. These types of complexes generally serve persons who need more assistance than other supportive housing options can offer.

Board and care homes – providing meals, supervision, and limited assistance in daily activities – number over 30 000 in the United States, more than double the number of nursing homes. However, most of them have only 5 to 20 units and therefore house only about one-fourth the number of residents (about 400 000 persons) in nursing homes; half of their residents are under 62 years of age. Although most board and care homes are privately run, many residents receive state government subsides as well as

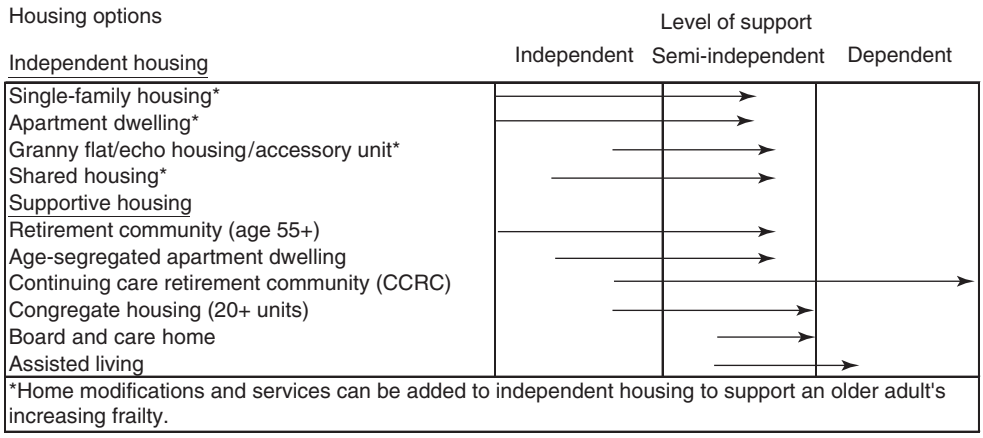

Figure 1 The continuum of housing. Independent: living arrangements designed for individuals and couples capable of handling their own housekeeping, cooking, and personal care needs. Semi-independent: living arrangements designed for those with some chronic limitations. Residents are self-sufficient and capable of self-care, but may rely on the facility for meals, housekeeping, and transportation. Dependent: living arrangements that provide 24-hour supervision, intermittent services, and nursing care for severely impaired individuals. Reproduced from Evashwick, C. J. (2005). *The continuum of long-term care*, 3rd edn. Delmar Learning, a division of Thomson Learning: www.thomsonrights.com.

Supplemental Security Income (SSI). Most board and care homes are very modest in nature and require that residents share rooms. State governments regulate these homes, but many of the smaller ones are unlicensed and enforcement can be lax.

Assisted living, a rapidly growing form of housing in the United States, generally provides independent apartment units (usually including private bathrooms and sometimes kitchens), professional management, and a full range of personal care services, including dispensing medications. The attractiveness of assisted living for older persons and their families is attributable to its homelike design, the desire to maximize privacy and autonomy within the dwelling unit, and the availability of more personal care services such as dressing and bathing assistance. Very frail individuals, including those who are incontinent and those with Alzheimer's disease, view assisted living as an alternative to the hospital-like environment of the typical nursing home. Currently, assisted living in the United States is primarily available to middle- and upper-income older persons who can afford it.

Location

The location of housing can have a major impact on the lives of older persons. It is particularly important for older people to have safe neighborhoods with a range of public and private facilities and good public transportation. Older persons can be especially vulnerable to urban change when they are frail, strongly attached to their homes, and possibly locked in by low home prices or inability to afford higher rents. Older persons report less satisfaction with their neighborhoods than with their housing. In rural locations, older people can be isolated from essential services and social contact, particularly if they cannot drive a car.

Markets and government policies have substantially restructured US cities over the last generation. As new cohorts of individuals in the middle classes moved outward from the central cities, established homeowners have grown old in neighborhoods undergoing major changes in environmental amenities and racial composition. Private tenants have faced rising rents, public or private redevelopment, and conversion of apartments to condominiums. Owners in deteriorating areas may be trapped by falling house prices. In revitalizing areas, owners may be presented with opportunities to cash in on rising property values and move elsewhere.

A recently recognized phenomenon is the concentration of older persons in areas that attracted them but were not intentionally planned for them. Twenty-seven percent of older people live in a building or neighborhood where more than 50% of the residents are over age 60. In many of these buildings and neighborhoods, older persons have aged in place, having moved into them when they were in their 40s, 50s, and 60s. In some situations, the mutual support and security of living with one's age peers have drawn older persons to these settings from other places. In other places, the out-movement of younger cohorts in search of employment has resulted in an increasing percentage of older persons. Referred to as naturally occurring retirement community (NORCs), these communities do not generally offer the social

and health services that older persons need as they age. NORCs provide the opportunity to take advantage of potential economies of scale by clustering services, developing new facilities (e.g., senior centers), and linking housing with services.

Over the last decades, increasing numbers of people have been aging in place in single-family homes built in post-war suburban areas. These areas were designed for travel by car and thus have relatively poor public transport and access to private and public facilities. Compared to older inner city areas, the suburbs can present major spatial barriers to people who do not drive cars and may have difficulty walking. They also have a limited range of housing types, sizes, and costs for those who wish to move to more appropriate housing in a nearby area. These potential difficulties could be minimized by land use policies that ensure a mix of land uses and housing types in new as well as established areas of cities.

Housing Policies and Programs

Since World War II, almost all Western industrialized countries, including the United States, have taken some responsibility to ensure that their citizens have access to decent and affordable housing. Because they are mixed economies and the private sector plays an important role, many of the policies have attempted to provide a stable economic climate so that the private housing industry, a major sector of the economy, can produce an adequate quantity of housing and employment in the building industries. In the United States, national housing policy has consisted of federal mortgage guarantee programs, the establishment of a secondary mortgage market, and tax incentives for home ownership. These policies have had strong political support, especially among builders and realtors, who are powerful interest groups at all levels of government. The elderly, with the highest rates of home ownership, have been major beneficiaries of these overall housing policies.

Governments have also sought to provide housing specifically for vulnerable groups that are not well served by the private sector. In order to simulate production of housing for the poor, governments have either built complexes themselves or provided subsidies to profit and/or non-profit developers for the construction of rental housing. Some countries such as the United States and Britain have developed a substantial stock of housing for low- and moderate-income older persons, using supply-type programs. The early supply-oriented programs for the elderly have initially emphasized the shelter and low-cost aspects of housing. In response to the growing number of very frail older persons, more recent approaches have stressed the inclusion of services.

Demand-oriented strategies include programs that provide housing allowances or vouchers so consumers can pay more for better housing. Demand-side approaches tend to be more acceptable to conservative political parties, which resist direct government efforts to increase the supply of public or welfare housing. The following discussion analyzes four housing programs that illustrate supply-and-demand strategies governments have used to improve the housing situation of the elderly.

Age-Specific Housing for Independent Older Persons

Governments in many countries provided subsidized, age-specific housing for independent older persons only after the most severe post-war housing shortages had been relieved in the 1950s by housing supply programs focused on meeting the needs of young families. As home ownership became possible for families with even modest incomes, subsidy programs in the United States were viewed as permanent housing for low-income families, many of whom were minorities. In 1956, the eligibility requirements were changed to allow single older persons to live in public housing. Increasing numbers of older people began to be served by these programs for three basic reasons: (1) elderly tenants had lower incomes, fewer assets, and poorer housing conditions than younger renters; (2) long-term residents of subsidized housing programs began to age in place; and (3) the elderly were viewed as the deserving poor and were considered less problematic as tenants than younger adults with children.

As older single persons began to move into projects that had previously housed only families, concerns were raised about their safety and potential alienation. At the same time, experts in the emerging field of gerontology began to advocate for age-specific housing for the elderly that would have specific design features (e.g., emergency call buttons, few or no stairs), common space for socialization, and services such as meals. Psychologists and social scientists were concerned about older persons' ability to adapt to such a radical new lifestyle and the potential isolation of large groups of older persons living in age-segregated high-rise buildings. These fears were put to rest, however, by studies finding that residents of age-specific housing, compared with tenants in the community, reported greater morale and life satisfaction, increased friendship formations, increased social interaction, and better perception of health status. By the early 1990s, 37% of public housing

units were occupied by the elderly, with more than 300 000 older persons residing in projects exclusively for the elderly and disabled and a comparable number of older persons living in family projects.

A step up in quality from public housing in the United States is housing for the elderly provided under Section 202 of the National Housing Act of 1959. As originally enacted, Section 202 provided direct, low-interest loans to non-profit sponsors (mostly religious organizations) to provide housing for moderate-income elderly tenants ineligible for public housing. Although these projects generally had more amenities than public housing (e.g., some provide congregate meals), they were also intended for independent elderly. Early advocates of the program did not want the housing to resemble homes for the aged. Consequently, the program did not fund services, and it permitted managers to bar applicants who could not live independently. This approach was consistent with the philosophy of the federal housing agency, which considered its responsibility bricks and mortar and not services. More than 250 000 units of Section 202 housing had been built by 1995.

Other advanced countries have also built government-subsidized housing specifically for older people. For example, in 1962, Peter Townsend, a leading academic, succeeded in urging the British government to develop sheltered housing as a non-institutional form of care. The term sheltered refers to purpose-built apartments with services ranging from an on-site manager to communal dining and homemaker services. Very sheltered housing, a somewhat later development, is similar to congregate housing models in the United States and provides extra wardens or domiciliary assistance to residents. Great Britain, Denmark, and Sweden have constructed purpose-built dwellings in small clusters with supportive design features and on-site managers. However, most European countries have provided for relatively independent older people mainly though public housing for all age groups.

Various forms of age-specific congregate housing have been sought after by older persons. They have also been popular with government officials, who acknowledge that, in contrast to many family projects, housing for the elderly has had few problems and has been well managed. Nevertheless, during the late 1980s, in the United States and other countries, these programs began to experience reduced government funding for new complexes. They have been viewed as relatively costly compared to other housing subsidy approaches, such as vouchers, and have lost favor with conservative governments. There has also been a growing perception that other groups have more pressing needs and that housing for independent older persons has failed to address the problems of very frail older persons. By the mid-1990s, governments in Europe, North America, and Australia were reducing housing programs for independent older persons or adapting them to serve frail older persons.

Supportive Housing and Assisted Living

By the early 1990s, many residents of housing for the elderly had aged in place and were in their late 70s or 80s with accompanying greater needs for physically supportive features and services. For the most part, these housing complexes and their managers were ill equipped to meet changing resident needs. At the same time, government concern with housing the elderly was shifting from independent housing to service-enriched housing. This emerging trend had been driven by the search for cost-effective alternatives to expensive nursing homes and the desire of frail older persons to live in residential rather than institutional settings. Consequently, in the last two decades, programs have been created to develop supportive housing that is physically accessible, contains special features, and has a range of services. Two basic strategies have been used to develop housing for very frail older persons: adapting existing housing originally intended for independent elderly and developing new forms of very supportive housing.

One approach to developing supportive housing in the United States has been to adapt government-assisted housing for independent elderly by better equipping it to serve frail older persons. Although concern about cost-effectiveness has limited the growth of service-enriched programs, such projects have nonetheless demonstrated that existing multi-unit housing complexes can be adapted to improve the quality of life of frail older persons and assist them in aging in place. With these goals in mind, Congress in the early 1990s allocated funds for service coordinators in a wide variety of government-assisted housing complexes for the elderly. Similarly, several years later Australia adopted an aging in place strategy that has emphasized keeping older people as long as possible in senior housing complexes such as hostels.

The difficulty of adapting existing housing and meeting the needs of very frail older persons for ongoing supervision has led to a very rapid growth in assisted living. Although it can serve very impaired older persons including those with Alzheimer's disease, assisted living has not been generally affordable for low-income persons. Wider availability requires melding income streams from diverse housing,

health, and income programs to pay for costs related to shelter and services. Over recent years, some states have utilized Medicaid to reimburse service costs through coverage under the Medicaid state plan or under a Home and Community-Based Services (HCBS) waiver. These waivers provide flexibility to states to develop innovative residential alternatives for Medicaid-eligible individuals who would otherwise need institutional care. As of 2000, 38 states had used Medicaid state plans or waivers to cover services in either assisted living or board and care facilities.

The US Department of Housing and Urban Development (HUD) has appropriated funds for the conversion and retrofitting of entire buildings or floors of Section 202 and other federally assisted housing projects for the elderly into assisted living facilities under the Assisted Living Conversion Program. The experience of this strategy indicates that it increases residents' access to services and provides a residential environment. In some cases, however, buildings were difficult and expensive to retrofit, especially to accommodate persons with Alzheimer's disease. Maintaining a residential atmosphere requires appropriate state regulations that stress privacy and autonomy as well as recognizing that there may be trade-offs in terms of safety. The enactment of such regulations depends on evaluations concerning quality of life considerations and cost savings relative to nursing home expenditures. The latter benefit has not yet been proven, and some groups have argued that because assisted living serves a population with impairments similar to those of residents of nursing homes, it should also be strictly regulated. The danger is that these regulations could shift assisted living away from a social model to a medicalized approach.

In Australia and the United Kingdom, there is increasing interest in unbundling the accommodation and care components of residential care. This means that older people could have high levels of care in a wide variety of housing circumstances – including their own homes and private retirement homes – rather than have to move to nursing homes. This widens the accommodation choices for individuals and shifts capital costs out of government aged care budgets. However, with shortfalls in provision of public housing, there is increasing concern over the affordability of housing and the availability of community-based services.

Home Equity Conversion Mortgages

With the erosion of the government safety net, increasing attention has been directed to ways in which older homeowners can access the equity in their homes without having to sell and move. Reverse mortgages allow older persons to draw out money based on their home equity and repay it after they move or die. The complications and risks of these loans, for both lenders and homeowners, have been reduced by federal insurance for home equity conversion mortgages (HECMs), which provide increased financial protection and security of occupancy for older persons. Nevertheless, the uptake for reverse mortgages has been relatively small, in part due to the high closing costs, the reluctance of older people to tap into a resource that they have saved for many years, and the security that home ownership provides. Over recent years there have been small increases in the number of HECMs due to such factors as reduced retirement income from bonds and dividends. Proposals have been floated to encourage or even require older people to draw down on their equity to pay for long-term care services or insurance, home repairs, and home modifications, thereby reducing government outlays. Such proposals, however, are unlikely to win support from older people themselves. Nevertheless, HECMs have been used for a variety of purposes by older persons such as paying off debts to avoid foreclosure, home repairs and modification, medical expenses, and long-term care. Continued expansion of this option for older persons will depend upon ongoing participation by the federal government in providing insurance, lower closing costs, and a more active involvement of the secondary mortgage market.

Home Modifications and Repairs

Since the early 1980s, governments have increasingly recognized the preference of older persons to remain in their own homes as long as possible. Policymakers have also begun to examine ways to make more efficient use of existing housing resources with emphasis on single-family homes. Based on the realization that many older persons lived in homes with an extra vacant bedroom, a movement developed to share homes. At the same time, there was increasing evidence that many frail older persons had homes that needed repair and modifications to help prevent accidents, make caregiving easier, and substitute for costly personal care services. Several studies suggested that home modifications were being held back by inadequate funding, enormous gaps in services, fragmented service delivery, and a low level of awareness concerning the efficacy of home modifications among consumers and professionals.

In the United States, home modification programs are highly reliant on programs such as Community

Development Block Grants and the Older Americans Act. Neither of these programs earmarks funds for modifications nor necessarily sets it as a high priority. In order to enhance the ability to age in place, a number of countries – such as Britain, the Netherlands, Canada, and Australia – have launched home repair and modifications programs that focus on upgrading individual units, as well as adding features such as ramps, grab bars, and roll-in showers. Inherent in the design of such programs are policy dilemmas concerning the extent to which payment for such changes should rely on loans, grants, or out-of-pocket expenses. A more fundamental approach taken in Australia and Europe is to require that all new dwellings – not just those for older people – meet age-friendly standards of universal design.

Policy and Research Directions

There are mixed prospects for the adequacy of housing for older people in the future. On the one hand, Baby Boomers entering old age over the next decade will have relatively high rates of home ownership that will cushion the financial adjustments to living on a fixed income. On the other hand, many older people will continue as lifelong tenants with few private options for accommodation or services. Major challenges for meeting housing and related needs include the increasing number of people reaching very advanced ages, accessibility difficulties for those growing older in post-war suburbs, and continuing severe restrictions on public expenditures. Although pronounced in the United States, these social and economic trends are also found in other industrialized nations.

The housing of older people in the future will be deeply affected by a wide range of government policies extending to taxation, income support, and regulation of property and land use. While housing situations and policies vary greatly among countries, several broad international directions are apparent. One approach is to provide integrated community care, which enables frail older people to remain in their own homes and limits the use of costly residential care. In many ways, the home itself becomes the care center. A second approach is to encourage older people who have the money to pay for their own housing and related services, whether purchased from the public or the private sector.

Directions in supportive housing for older persons have emphasized consumer-controlled services and new models of accommodation. Many of these initiatives require increased government flexibility, private–public partnerships, and innovative approaches. Their success depends on government involvement through developing and funding housing and services, providing information and technical assistance, and establishing a regulatory framework that protects the right of frail older persons and other consumers. The new directions aim to break down barriers between programs and to include housing as an integral part of the long-term care system. Moreover, understanding the needs of the older person requires a wider examination of the environmental settings in which older adults live. The creation of elder-friendly communities, which consider the location of stores, churches, or parks, the adequacy of sidewalks, and the legibility of signage as important determinants to maintaining independence, has received increasing attention in the United States. Future planning and policy initiatives must recognize the environmental context as key to helping older adults remain mobile and connected. In Australia and Europe, there is increasing recognition of the importance of land use planning in ensuring that neighborhoods provide people of all ages with a range of housing types and land uses near their existing homes.

A number of initiatives have promise to attract public support and yield major benefits for frail older people:

1. *Develop a consumer-controlled voucher system* that would enable older people to choose combinations of housing and services that fit their individual needs and preferences. By unbundling housing and services, portable services would provide a broader set of choices of where to live.
2. *Create innovative models of housing,* such as small-scale places for persons with Alzheimer's disease that are integrated into the community, and provide elderly with access to community facilities and intergenerational contact. New models of senior housing also need to address changing living arrangements, such as the growing trend of grandparents raising grandchildren. Policy changes are required because the majority of government-assisted housing for the elderly has been developed for their exclusive occupancy and does not allow children.
3. *Develop new forms of supportive housing* that provide very frail older people with increased privacy, autonomy, and choice. Assisted living and other home- and community-based long-term care options should be explored as potential substitutes for nursing home care. In addition, policy directions should emphasize the diversion of persons from nursing homes and the transition of nursing home residents to the community.

4. *Incorporate new technology* that can make it easier for frail older persons to summon assistance, access information, and carry out tasks independently. Home modifications, assistive technology, and smart home technology may be cost effective in their ability to delay institutionalization and prevent injuries.
5. *Encourage visitability and universal design*, which promote accessibility in newly constructed housing. Visitability refers to basic accessibility on the first floor of new housing through such features as a zero-step entrance, doors and corridors wide enough to accommodate a wheelchair or walker, an accessible bathroom, and an area in which a person can sleep. Universal design is a broader concept that promotes the use of housing and communities by all persons regardless of size, age, or disability. In addition to visitability features, it includes such features as accessibility from the front and back of the house, countertops of varying heights, controllable light switches at appropriate heights, and access to all parts of the house.

These directions involve many aspects of housing, including financing, housing and building codes, regulations, legal rights, modifying and retrofitting environments, and philosophies of management and care. Advances are already being driven by those who can pay for services such as home modifications or moves to a new setting such as assisted living. The choices for low- and moderate-income older persons, however, are much more constrained. Although a new system with greater consumer choice may create flexibility and new solutions, the magnitude of government support remains in doubt in the United States and other countries as housing subsidies are either capped or reduced. Many older persons continue to pay excessive amounts of their income for housing, live in deficient units, and are at risk of moving unnecessarily to more institutional settings.

Action to improve housing for older people needs to be based on sound knowledge. More research can reveal how life experiences, housing markets, and public policies influence people's housing on entry to old age and transitions through the course of old age. The impact of housing on older people's lives needs to be identified in terms of their standards of living, health, independence, and well-being. Rigorous analysis of housing programs can enhance their cost-effectiveness and increase their political attractiveness. Such a knowledge base requires a strong emphasis on housing as an important area for applied, multidisciplinary research.

See also: Frail Elderly; Human Factors Engineering and Ergonomics; Long Term Care.

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Human Factors Engineering and Ergonomics

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Glossary

Anthropometry – Measurement of the physical dimensions of the human body.

Biomechanics – The study of the forces and motions involved in human movement.

Human Factors Engineering (also called Ergonomics) – The discipline of scientific and technical endeavor aimed at optimizing the fit between people, their environments, their tools, and the tasks they perform.

Job Design – The consideration of contextual factors such as worker experience, task characteristics, and the method of assessment used to evaluate job performance.

Macroergonomics – The systematic analysis of organizational needs and how these are supported by the abilities of personnel within the contexts of the work environment.

Introduction

Human factors engineering, also referred to as ergonomics and hereafter referred to as HF/E, is a discipline of scientific and technical endeavor aimed at optimizing the fit between people, their environments, their tools, and the tasks they perform. HF/E is necessarily a broad field, covering the extent of human activity. Examples of HF/E work include designing a kitchen counter or industrial workbench for the height of the user, evaluating the physical strain of a lifting task (whether it be groceries into a car trunk or packages onto an industrial conveyor belt), designing a roadway sign so it can be seen at an adequate distance by drivers, creating warning labels that are effective deterrents to risky user behavior, and creating user-friendly controls and displays for computer software and consumer products such as cell phones, televisions, and dishwashers. There is a natural overlap between HF/E and gerontology. Much of gerontology is aimed at maintaining the functioning and independence of older adults, and there are active groups of HF/E researchers and professional practitioners who find the challenge of working for the benefit of older adults particularly challenging and rewarding. This article attempts to provide an overview of the field of HF/E for gerontologists engaged in research and professional practice.

This article is organized as follows: first, we provide an account of the history and background of HF/E, including a discussion of related fields, the primary sources for HF/E professional development, and HF/E research and development publications. Next, we provide an inventory of the many age-related changes and differences that HF/E professionals should bear in mind when designing for older adults, and how that information is considered from an HF/E perspective. Next, we consider some specific results of research and development in applications in areas of importance to older adults. Finally, we conclude with some trends that will be important for both gerontologist and HF/E professionals to consider for the future intersection of gerontology and HF/E.

Human Factors Engineering and Ergonomics – The Profession

It is commonly agreed among practitioners and academics in the field that HF/E has its roots in World War II. Seminal work in the field came from attempts to design better aircraft controls and displays, radar screens to best suit the cognitive and perceptual capabilities of operators, and other military applications. Tracing the roots of the discipline back further into history, one can see linkages to early industrial revolution era 'scientific management' practices promulgated by Frederick W. Taylor, Frank and Lillian Gilbreth, and their contemporaries. The word 'ergonomics' was coined from the Greek words for work (*ergo*) and law (*nomos*) by the Polish scientist Wojciech B. Jastrzebowski, in his 1857 work entitled 'An outline of ergonomics, or, the science of work based upon the truths drawn from the science of nature.'

Being inherently interdisciplinary, HF/E has natural overlaps with other fields of inquiry (see **Figure 1**). From the psychological sciences, the field draws on knowledge of fundamental processes and mechanisms of psychophysics, perception, cognitive psychology (including memory, attention, language processing, and decision making). From engineering and computer science, HF/E overlaps with and draws on areas such as artificial intelligence, software engineering and requirements analysis, signal processing, control systems

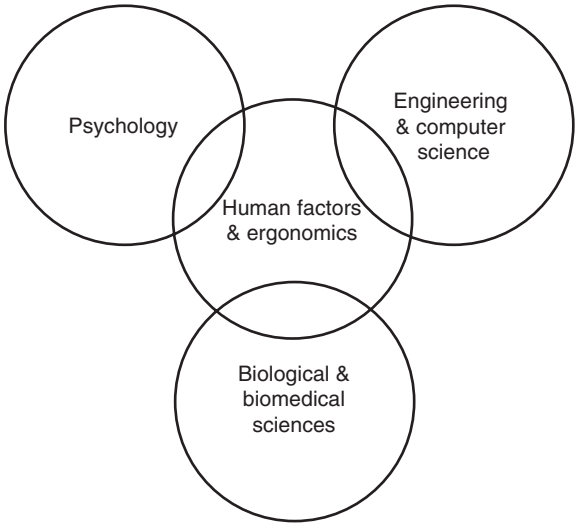

Figure 1 Interdisciplinary overlap of human factors and ergonomics with related fields.

engineering, biomechanics and other aspects of mechanical engineering, traffic engineering, and safety engineering. Finally, HF/E overlaps with the biological and biomedical sciences in areas such as exercise physiology, occupational medicine, and industrial hygiene.

Professional development in HF/E is supported by numerous professional societies, opportunities for certification, and professional publications. The largest and most renowned HF/E societies include the US-based Human Factors and Ergonomics Society and the International Ergonomics Association. Professional certification is handled by the Board of Certification in Professional Ergonomics. Major journals in the field include *Human Factors*, *Ergonomics in Design*, *Ergonomics*, *Applied Ergonomics*, *International Journal of Human–Computer Interaction*, *International Journal of Industrial Ergonomics*, and *Human Factors and Ergonomics in Manufacturing*.

Normal Aging and Human Factors

What does it mean when someone refers to a person as an older adult? Are they merely describing their chronological age or are they referring to underlying changes in a person's functioning? This question is much more complex than it seems. While chronological age is the marker used by most of society to define when a person becomes 'old,' this provides little useful information toward understanding the older person's capabilities and limitations.

There are a number of changes associated with the aging process. Some of these changes are considered to be 'normal' aging, while others are typically associated with age-related disease. This article is concerned with those changes that occur in the absence of pathology. The impact of age-related impairment can be quite severe and can limit a person's ability to work, recreate, and live independently. Human factors specialists are interested in changes that functionally affect ability and, consequently, human performance. This article examines such changes to the sensory system, changes in cognitive function, physical changes, and the impact of skill and expertise.

Visual and Auditory Perception

There are many changes that occur in the aging visual system. One of the most common visual problems experienced by older adults is change in the ability to focus. There are several visual characteristics that relate to the ability to focus on an object. First is the change in visual acuity, or the ability to perceive the finest details of an object. By 80 years of age, acuity experiences a 50% decline on average. In addition, older adults experience problems with accommodation, the ability to focus on objects at different distances. Primarily, the point of resting accommodation and the near point recede, causing an increase in the distance required to accurately view a visual target. There are also more instances of hyperopia (farsightedness) and fewer instances of myopia (nearsightedness) in the elderly population. These functional changes limit human visual performance in many tasks. Often, the older adult is unable to read signs, labels, warnings, and instructions, and consequently may be inadvertently placed at risk. Many designers advocate the use of large fonts for older adults.

Other visual changes observed in older adults are related to illumination. There is a decrease in the amount of light that reaches the retina, implying a need for higher source illumination. However, the slowing in the rate of accommodation creates heightened susceptibility to glare and longer times for adaptation to and recovery from glare sources. It is important to balance the needs for sufficient illumination and glare avoidance in order to promote effective visual performance. Some basic recommendations include providing multiple light sources of lower intensity, shielding the light sources, locating the light sources outside of the visual field, and making sure that illumination levels do not fluctuate.

These visual changes impact the performance of work-related tasks. In laboratory tasks involving visual attention and visual search, older adults exhibit difficulty in ignoring irrelevant information. Mead and Fisk suggested that the use of visual features to draw attention (color in this specific case) may not be

sufficient unless the older adult is trained to look for those features. In vigilance tasks, older adults show little difference from younger adults, unless the visual image is degraded.

Auditory impairments due to aging are hard to identify. There is an inherent conflict between age effects and exposure effects. However, some consistent patterns do emerge. Older adults exhibit decreased sensitivity to higher frequency tones, known as presbycusis, and have difficulty with speech perception in noisy or highly resonant environments. Older adults are also negatively affected by time compressed auditory information. The implications of these impairments are most significant in public environments. Many environments, such as workplaces, shopping centers, and restaurants, are quite noisy and have had little design effort put into damping the noise sources. On the job, this can mean difficulty communicating with co-workers and difficulty detecting auditory warnings and signals. Important auditory information should be presented in both auditory and visual modalities to minimize any risk for misinterpretation of the information.

Memory

It is well acknowledged in the aging literature that memory deficits occur with age. Theories describing the source of these deficits can be categorized as resource-, stage-, or systems-based. While the theories provide insight into the underlying constructs, human factors is concerned with the functional limitations caused by age-related memory impairments.

Much of the research on memory and aging has stemmed from resource theories. Older adults have a diminished working memory capacity that is primarily limited by the processing demands of the task. As tasks require higher levels of processing, older adults exhibit reliable deficits in performance. Some researchers link these age-related deficits in working memory to the slowing of perceptual speed, particularly as task complexity increases. Retrieval, a component of stage theories, has also been shown to be more difficult for older adults by observed performance deficits during free recall tasks. However, a potential conflict exists in sorting out the source of the deficit, be it processing or retrieval. Additional evidence of age-related retrieval problems is the tip-of-the-tongue phenomenon whereby older adults experience greater trouble retrieving familiar words or names. Spatial memory is also susceptible to age-related deficits. Research has typically demonstrated that older adults have difficulty in spatial memory tasks that involve remembering where an item was located within a given spatial context.

The implications of memory impairment can be quite severe for older adults who wish to continue working and living independently. In highly dynamic work environments, an older adult may be required to manage several tasks or projects at a given time and may be under time pressure to complete those projects before deadline. The research on working memory and perceptual speed suggests that these requirements would place a much higher burden on the older worker than the young worker. In addition, older worker performance may suffer if it is necessary for the worker to recall detailed information without the aid of context. In the home, these same deficits can make independent living more difficult. However, the older adult may have the opportunity to use strategies to simplify the performance of home tasks. For example, the older adult may choose to attend to only one task at a time (e.g., cooking) and may identify fixed locations for valuable items (e.g., keys).

Attention

Multiple task performance refers to the ability to simultaneously perform two or more tasks, with competing demands on perception, processing resources, and response. The multiple task performance of older adults is particularly impaired and is represented by small sequential responses of perception–processing–response. The attentional demands of multiple tasks often lead to delays in perception of new stimuli and performance of the response as well as missing other information or stimuli due to fixation with the multiple tasks. The most significant impairments in divided attention are found in tasks of greater complexity. However, the type of tasks used in the multi-task paradigm is critical to understanding the performance impairments. Older adults suffer larger performance deficits for tasks that combine unrelated processing requirements, while no age-related differences are identifiable for tasks that use meaningful speech. Similar results have been shown for auditory information. Shadowing tasks revealed age-related differences when information presented to different ears was in conflict. An age-related deficit was also noted in the time to switch attentional focus between ears.

Attention deficits can be damaging in the workplace and the home environment. If the task demands are overwhelming to the older adult, there is a risk of missing information that can be critical to production or safety. It is important to recognize what Tun and Wingfield called the threshold of functional adequacy. This threshold is situation dependent and separates adequate performance from inadequate

performance. For example, if the difficulty of a given task increases (such as adding additional attentional demands), the decrement in performance may or may not be equivalent for the older person and for the younger person. It is not this interaction between age and difficulty that is critical, but the absolute performance level of the individual that dictates if performance is still functionally adequate. Thus, whether or not an older individual is differentially impaired relative to a younger person, their performance may be lower overall, causing them to go below the threshold of functional adequacy.

Anthropometry and Biomechanics

The goal of human factors specialists is to design to accommodate human characteristics. One application that is driven by this principle is the area of anthropometry. Anthropometry is the measurement of the physical dimensions of the human body. Large-scale databases exist that describe many of the human physical dimensions. However, these databases were developed from measurements of US military personnel and do not necessarily reflect the general population, particularly the older population. Within a narrowly defined age cohort, there tends to be large interindividual variability due to factors such as body type and bone structure. There is also a high level of intraindividual variability due to many health-related factors and moderated by age as well. Age-related changes become most pronounced after the age of 60; however, height begins to decline as early as age 30 at a rate of about 1 cm/decade. The magnitude of change of most physical characteristics is still relatively unestablished. It is commonly observed that as men age, they lose weight, and as women age, they gain weight. However, little scientific data have been collected on older adults. The data that do exist generally are from small sample sizes, cover large age ranges, and are often averaged across males and females. This lack of data, combined with the knowledge that variability increases with age, means that the human factors designer has little information to apply to the design of physical spaces for older adults.

The design of the workplace and the home environment also requires consideration of human strength capabilities. The study of biomechanics is concerned with describing the forces and motions that are involved in human movement. Strength is one aspect of biomechanics that has been demonstrated to decrease as a function of age. In particular, measures of isometric maximal force productions indicate that strength peaks at about 30 years and then declines across most muscle groups. Even though certain neuromuscular changes can be linked to these declines, there are questions about the role played by inactivity and muscle disuse. While it is clear that maximal strength decreases, submaximal work shows little effects due to age. This can perhaps again be related to the concept of functional adequacy, but evidence also exists that older individuals employ compensatory mechanisms that minimize the functional deficits. It is only in the later decades of life that these deficits can not be overcome.

Motor Control

Age-related declines in motor control can be summarized as a slowing of behavior. In particular, this slowing is apparent as increasing reaction times and increasing movement times. While a moderate effect has been noted for simple reaction times (a single stimulus is anticipated and the appropriate response is known), this effect is amplified when the problem becomes more complex, as is the case in choice reaction times (an element of uncertainty is added, with multiple stimuli and/or multiple response choices). As the task uncertainty increases, the stimulus–response compatibility decreases, and as the response modality becomes more difficult (manual rather than vocal), predictable increases in reaction time are observed.

Movement time also suffers age-related declines that are related to the uncertainty and complexity of the motion. Older adults tend to make movements that are slower, less smooth, and less coordinated. Continuous movements are also more problematic; it has been observed that older adults will modify the continuous movement task into a sequence of discrete movements in order to simplify the motor control requirements. In addition, older adults have difficulty if a task requires precise control and force modulation. These deficits can be attenuated with physical activity and training. Connelly *et al.* demonstrated improved smoothness of motion, a decrease in time taken to reverse motion direction, and less deviation from criterion in the motion pattern after just six training sessions using isokinetic ankle movements.

The observed trends in reaction time and movement time suggest that requirements for quick responses may be problematic as one ages. However, the threshold of functional adequacy must again be examined in this context. While most tasks do not demand such limiting thresholds, it is possible that reaction and movement time could be critical if the task involved prevention or recovery from an accident. For example, can the older person respond to an alarm in sufficient time to minimize damage and injury? Can the older person move fast enough to get

out of the way of automatic machinery? These response limitations must be examined in context.

Skill and Expertise

The effects of aging on performance are typically represented by declining function. However, these declines can be moderated to some degree by skill and expertise such that the functional difference between young and old is negligible. Skill is directly linked to practice, whereby practice is the process of skill acquisition. There is evidence that practice can mediate age differences for some tasks such that older adults can attain performance levels comparable to younger adults. In particular, practice reduces the age by complexity effect and reduces the variability in motor control tasks. Practice may provide older users with the opportunity to develop alternative strategies of performance for tasks that have become more difficult. However, acquisition of new skills should build on existing knowledge to compensate for the declining cognitive and motor resources of older adults.

On the other hand, expertise incorporates an element of experience obtained by repeatedly utilizing a skill over time. Morrow and Leirer proposed that the age-related decline in cognitive resources is offset by the increased knowledge and experience acquired with age. Experts compensate for their declining abilities by finding new ways to perform old tasks. This usually involves the development of strategies, such as keeping appointment books and performing collaborative work. Experts also develop accommodation strategies whereby they redefine how to accomplish a given task in order to avoid task requirements that cause them difficulty. For example, many older adults choose to drive at off-peak times in order to avoid traffic congestion.

Human factors specialists should take advantage of the positive impact of skill and practice. It is critical that older workers maintain proficiency through continual application of skills. Regular training sessions may also benefit older workers by allowing them the opportunity to develop alternative performance strategies or by reinforcing the skill set already possessed. However, one should use caution when assigning an older worker to a new task. There should be some thread of continuity between tasks such that the worker's skills can be directly applied in the new context.

HF/E Applications and the Older Adult

Detailed knowledge of the physical, cognitive, and perceptual changes that occur with age has been utilized to address the needs of older adults in a number of areas. To achieve goals such as enhanced safety and life satisfaction, HF/E professionals act to ensure that the demands of daily tasks are commensurate with the abilities of older adults. Task demands are often defined in terms of activities of daily living (ADLs) and instrumental activities of daily living (IADLs). While both ADLs (e.g., bathing, dressing) and IADLs (e.g., money management, using the telephone,) are required for health maintenance and continued autonomy, IADLs are more complex and have traditionally been targeted for intervention. While an exhaustive review of the different areas of HF/E application is beyond the scope of this article, topics covered here include areas that address safety, increased independence, and work in later life.

Safety

Within the domain of safety, HF/E professionals have made numerous contributions such as tailoring warnings to facilitate older adults' comprehension of general hazards as well as collaborating with medical professionals to improve medication adherence and home medical device design.

Warnings One approach to preventing personal injury or property damage is to use warnings to inform those at risk about potential hazards and to promote safe behavior. Because warning comprehension is dependent on a number of perceptual and cognitive abilities, older adults have specialized needs that should be considered by warning designers. For instance, an older adult with visual impairment might not notice a written warning presented using small type size and thus be more susceptible to injury than younger adults. Likewise, age-related cognitive declines tend to place older adults at a significant disadvantage when they encounter pictorial warnings (e.g., a cigarette with a slash negation sign used to indicate 'no smoking' while pumping gasoline) that require the use of inferences to comprehend the nature of a hazard. In general, HF/E interventions to facilitate safety within the warnings domain have focused on designing age-appropriate warnings that attract attention and minimize dependence on inference. One area where such age-specific interventions have focused is the design of medication labels for the purpose of improving medication adherence.

Medication Adherence Medication adherence is defined as taking a medication at the correct times and at the indicated dosage, and following any special instructions as directed by a physician. A large percentage of non-adherence is due to under-use of the

medication, in large part due to forgetfulness. Factors such as complexity of schedule, number of prescribing physicians, and number of medications all tend to correlate with non-adherence. HF/E interventions designed to increase medication adherence have included the use of voicemail reminders, attempts to improve doctor–patient communication, and designing individualized pill organizers using different instructional formats. While each method has met with varying degrees of success, an understanding of how age interacts with the cognitive requirements of the task was most valuable in terms of guiding design of future technology interventions that are not yet in widespread use. One new application area for technological intervention is home medical device design.

Home Medical Devices Relatively recent changes in the health-care system have forced older adults to take a more active role in their personal health care. On a daily basis, older adult patients and caregivers must interact with devices such as blood glucose monitors and flow meters that were not designed for use by laypersons in a non-clinical setting. Evidence suggests that older adults are at risk and demonstrate an increased likelihood of making clinically significant errors when using home medical devices due to insufficient training and poor device interface design. HF/E contributions have focused on identifying age-related sources of error (e.g., device menu navigation, tactile insensitivity) and improving safe device usage by developing effective training programs that teach skills that can be retained over time.

Increased Independence While safety is a basic concern for people of all ages, older adults are also motivated to maintain an independent lifestyle. To remain independent, older adults must find solutions to transportation and communications problems that limit their ability to interact with others.

Transportation Barriers to mobility comprise one of the most profound constraints on older adults' independence. Consider the difficulty of accomplishing daily tasks such as going to the doctor or buying groceries without an effective means of transportation. Potential HF/E interventions have been investigated for a number of transportation issues such as difficulties experienced while using public transit systems and driving. For instance, motor control and related strength limitations might impair an older adult's ability to board a public bus, take a seat, and then exit at the intended destination. Design solutions to public buses might include lower stairs to facilitate boarding and exiting the vehicle, long-handled grab bars to assist balance, and ergonomic chairs that ease egress. Other public transportation issues that have been investigated are the cognitive difficulties associated with wayfinding. Many older adults report difficulties in determining which bus or subway train to take, when it arrives and departs, and how to navigate effectively to the intended destination. Solutions such as sign and map improvement promise to address these problems in public transportation as well as driving.

Although the tasks of driving and using public transportation share many of the same barriers to mobility, these barriers are amplified during driving. Estimates indicate that older drivers have higher crash rates per vehicle per mile driven and that they have higher fatality rates than younger drivers when accidents occur. These data have been attributed to age-related declines in visual search, attention, and slower reaction times. Attempts to reduce older adult traffic fatalities have included HF/E signage interventions that have focused on using redundant signs, reducing clutter from competing signs, and manipulating the physical characteristics of signs to make them salient and noticeable. Increasingly, advances in technology have also been adopted to reduce accidents. For instance, vehicles with proximity sensors should help older drivers to avoid accidents, whereas onboard navigation systems can provide cognitive support to assist with route or destination tracking.

Communication While transportation difficulties can physically limit the ability of older adults to interact with others, communication difficulties can result in social isolation. To effectively communicate with others and function in today's society, older adults are faced with the challenge of using a variety of technologies ranging from telephones to the Internet. Although few older adults report problems using their familiar household telephones, the ubiquity of these devices has been used to enhance their functionality by linking them to new technologies such as automated voice menu systems. Whether an older adult uses the telephone to purchase airline tickets, refill a prescription, or pay the electric bill, the likelihood of encountering an automated voice menu system is quite high. Given the cognitive and auditory demands of using such a system, older adults are at a disadvantage when they encounter them. HF/E interventions to improve automated menu systems have focused on decreasing the speed of presentation and providing cognitive support in the form of visual aids that promote navigational efficiency.

Another trend in communication technology is the adoption of cellular telephones. Cognitive difficulties

with menu navigation are accompanied by perceptual limitations when older adults use these devices. Because cellular telephone designers continue to follow the miniaturization principle by making their products smaller and smaller, older adults are increasingly being placed at a functional disadvantage. Given the number of documented age-related perceptual and motor control difficulties, it is not surprising that older adults report difficulty seeing the small numbers on a cellular display or having difficulty dialing via the small keypad. HF/E interventions have begun to address these usability issues by investigating how age impacts the characteristics of cellular telephone interfaces.

Perhaps the largest growth in new communication technology use by older adults has been their increasing willingness to use computers and the Internet. Older adults 65 and older report that they use computers to interact with friends and family as well as to find information about health care and increase job productivity. Because all of these activities are related to maintaining independence, HF/E researchers and practitioners have focused on making computer systems as accessible and usable as possible for older adults. Efforts to facilitate human–computer interaction (HCI) have ranged from improving the acquisition of basic computer skills (e.g., mouse control, desktop navigation) to the design of elder-friendly Web sites that provide perceptual (e.g., text in large type size sans serif font) and cognitive support (e.g., intuitive menu labeling and organization) to older adults. Basic HCI research has encompassed a large number of areas such as the ability of older adults to use various input devices and displays and system navigation issues. These findings have been applied as HF/E interventions to enhance functionality with a wide variety of devices such as automatic teller machines and library search engines in an effort to improve older adults' quality of life.

Work in Later Life

For a variety of reasons such as financial and esteem needs associated with job satisfaction, older adults are remaining in the workforce longer and the retirement age is steadily increasing. HF/E as a profession has focused on adapting the work environment to the abilities of the worker. Thus, the goal of using HF/E interventions to improve older adults' experiences in the workplace can be achieved through macroergonomics as well as adapting the workplace through training and job design.

Macroergonomics Macroergonomics is defined as the systematic analysis of organizational needs and how these are supported by the abilities of personnel within the context of the work environment. To this end, the goals of the organization must be identified and the structure of the organization must be evaluated in terms of how technology, personnel, and environmental variables interact to influence productivity. If, for instance, an organization's goals are expressed as a raw measure of output per unit worker in a physically demanding factory environment, the likelihood that an older adult will be viewed as competitive with younger co-workers is low. Thus, the effectiveness of an organization as a whole is evaluated at the macroergonomic level, whereas analysis at the level of individual workers and teams of workers is considered to be the microergonomic level. Training and job design are two HF/E methods used to tailor the work environment to meet the needs of older workers.

Training Rapid technological changes in the workplace such as hardware and software upgrades often necessitate the need for an older worker to update his or her skills through training. Thus, to meet the demands of a job, older workers must be able to update their skills, knowledge, and abilities. Given current knowledge of age-related changes in cognition, the need for age-appropriate training programs is essential. HF/E recommendations to develop training programs for older adults often include guidelines such as taking advantage of their experience and introducing new ideas in the context of familiar cues while minimizing the introduction of irrelevant or distracting instructional materials.

Job Design Job design refers to the consideration of contextual factors such as worker experience, task characteristics, and the method of assessment used to evaluate job performance. One method for matching task characteristics with the abilities of the older worker is to compare the knowledge, skills, and abilities (KSAs) necessary for a job to those possessed by an employee. The relative weighting of KSAs may be different for different ages. For example, investigations of cognitive tasks indicate that older workers may rely more heavily on their past experience and accumulated task-relevant skill set to solve problems, whereas younger workers may be more likely to rely on reasoning and general problem-solving skills. Likewise, age-related differences in perceptual and physical characteristics of workers must be considered. HF/E interventions have traditionally focused on reducing age-related difficulties through proper workplace/tool design, reorganization of procedures, and the provision of work aids such as power-assisted lift devices to offset strength

limitations in material handling. An example of workplace modification might include the use of a screen magnifier on a computer screen to offset age-related declines in visual acuity. Procedural manipulations that might allow employers to further maximize work output include assigning tasks based on KSAs rather than worker availability and providing breaks to workers of all ages.

Philosophical Issues and Emerging Trends in Human Factors and Aging

There are some significant philosophical issues and emerging trends that will need to be addressed by those who are working at the intersection of gerontology and human factors engineering. The first issue is the common misconception that the intersection of gerontology and HF/E is 'design for the elderly.' A second issue, related somewhat to the first, is that the population in general, and in particular the population of the oldest-old, is changing dramatically and rapidly.

Consider the depiction of HF/E with respect to gerontology as 'design for the elderly.' The very idea of 'design for …' is manifest in stigmatizing designs that point out the weakness and vulnerability that can come with advanced age, and can signify a paternalistic approach taken by designers. Marketing agencies and popular media are aware of this pitfall – images we see in magazines and television advertisements for products aimed at older consumers typically depict vibrant, healthy-looking, slightly graying-at-the-temples users of their products to hint at the intended market. The essence of a good design is that it will work well for the broadest range of users possible. An emerging field, universal design, which has its roots in the civil rights movement of people with disabilities, is advocating this approach. The 'design for …' idea has been decried and countered in the ergonomics-related research of participatory design (PD). The PD approach focuses on gaining an in-depth understanding of the group of intended beneficiaries of the HF/E intervention, focusing on building teamwork between all participants, and coming up with a solution that is sensitive to the social and emotional needs and concerns of the users, rather than just focusing on functional requirements derived from engineering models of the user-environment system. For HF/E interventions to reach their full potential, they will need the full participation of older adults and gerontologists, rather than just a blunt targeting of a vaguely or even inappropriately defined audience. This brings us to the next point.

The notion of 'design for the elderly' is, further, a drastic oversimplification exemplified by the difficulty in answering the following question – who are 'the elderly'? As gerontologists are commonly aware, population heterogeneity increases with population age. While it is true, as described in the earlier section on age-related changes, that there are reliable shifts in the mean on any given measure of functioning, it is also true that population variance increases dramatically, even on 'normally aging' population characteristics. HF/E has traditionally concerned itself with younger adults and 'normal' population characteristics. For example, the standard anthropometric envelope to target for accommodation has been from the 5th percentile to the 95th percentile of the population. The incredible diversity of the older adult population should challenge our notions of normal aging-related changes in function and encourage a closer look at meaningful ways to distinguish subgroups from each other, such as distinguishing otherwise healthy 'young-old' adults in their 60s from chronically impaired 'old-old' people in their 90s. The balancing act for HF/E theorists will be to continue to search for universals in human experience with tools, tasks, and environments, with which predictive and generalizable models of human performance can be constructed, while at the same time properly focusing and defining the subject matter of the proposed HF/E intervention and being sensitive to the intended beneficiary.

See also: Attention; Balance, Posture and Gait; Disability, Functional Status and Activities of Daily Living; Driving Behavior; Epidemiology; Hearing; Memory; Motor Control; Vision; Work and Employment: Individual.

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Relevant Websites

http://www.bcpe.org/ – Board of Certification in Professional Ergonomics.
http://www.iea.cc – International Ergonomics Association.
http://www.hfes.org – Human Factors and Ergonomics Society.

Humor

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Glossary

Humor – Disposition or attitude, expressed physically through laughter, caused by the painless resolution of a contradiction or synthesis of contraries, especially those concerned with topics and experiences capable of provoking anxiety, self-repression, or negative emotions.

Introduction

Humor can be understood as a disposition or attitude, expressed physically through laughter, caused by the painless resolution of a contradiction or synthesis of contraries, especially those concerned with topics and experiences capable of provoking anxiety, self-repression, or negative emotions.

Since the facts of human aging and the omnipresence of older adults are commonly, if erroneously, associated with decline, disability, and death, it is not surprising that the elderly have often been the brunt of jokes, even ones told by same-age peers. Negative humor about aging and the elderly focuses on subjects such as sexual impotence, physical changes and disabilities, and fear of death. Humor is used as a safety valve or distancing mechanism for suppressed fears and anxieties about human mortality. But there are positive forms of humor about aging, often produced by the elderly themselves. These reflect humility and acceptance of limitations associated with growing old as well as some of the advantages and strengths that come with age and experience. Wisdom may be expressed through humor because many of life's most profound lessons arrive in the form of paradoxes that can best be expressed through a sigh, jest, witticism, or knowing smile.

Humor may be thought of as a stimulus, mood, attitude, disposition, or way of looking at the world. Humor shows itself in images of the elderly, as a set of therapeutic techniques, and as an aspect of cognitive and affective development.

Concept of Humor

The Word Humor

The English word 'humor' has a revealing history. It comes from the Latin *humere*, meaning 'to be moist.' Ancient and medieval treatises on physiology postulated that the human body had four fluids, or 'humors': bile, phlegm, choler, and blood. The relative proportion or balance among these humors would determine a person's health and temperament or disposition. Medieval medical authorities thought that increasing dryness and cooling off characterized aging. Hence, a lack of humor (moistness) was associated with aging and the elderly. The characterization of an older person as 'dried-up' may have its origins in this early medical speculation.

Modern views of humor transform the medieval material concept of fluids into metaphorical ones. The description of having a good sense of humor, an aspect of happiness, continues to suggest the idea of a well-balanced person who experiences the world with a certain degree of equanimity. Ironically, the mechanics of humor are often related to imbalances, as when we are thrown off guard, surprised by a joke, witticism, irony, double entendre, sight gag, mime, or pratfall. Humor is the resulting disposition of a specific form of the comical. So to understand humor and its connection to aging and the elderly, it would help to understand the structure of comedy.

Aristotle's Concept of Comedy

Aristotle, in *The Poetics*, distinguished the dramatic form of comedy from tragedy. Both forms involve a collision of will – usually that of a prominent public leader such as a king, queen, or general – with larger social and cosmic forces such as tribal taboos, family allegiances, wars, and injustice. In tragedy, flaws of human character result in pain: disgrace, downfall, and death. The cosmic realm asserts its dominion over human desires. But in a comedic drama, according to Aristotle, the individual escapes this destiny, rising triumphant over obstacles and counterforces through tricks, guile, or subterfuge, surviving humiliation, failure, and degradation. What might stand as a flaw of personality (e.g., excessive pride, foolishness, naiveté, impulsiveness) becomes, through inversion, a redeeming quality that turns the tide.

Ancient tragedy and comedy have their origins in religious rituals and, like rituals, have the function of releasing emotions of awe, fear, and pity. The dramas inculcate moral lessons by producing experiences in audience members that, through sublimation in the form of tears or laughter, bring their lives back into harmony with the social order or cause them to reflect on the need to adapt to radical changes taking place in that order.

The laugh of humor can express many things but, as Aristotle's delineation of comedy shows, humor depends on both a cognitive and affective process; it concerns topics of great seriousness; contraries or contradictions are involved as deviations from the expected, producing both surprise and insight. Humor has both 'low' and 'high' forms, the former based on making fun at someone else's expense (an individual or group), the latter pointing to features of the shared human plight. Although humor can be revelatory, it can also be escapist.

Negative and Positive Humor about the Elderly

Negative Humor about the Elderly

In a 2003 study, researcher Alan Bowd found that of 4200 jokes examined, 102 employed a predominant stereotype of older persons. These included the impotent male, the unattractive female, the vain and virile male, the disinterested female, the innocence of second childhood, the insatiable female, the forgetful old person, and the infirm old person. A single example illustrates the typology.

An old man, perhaps in his 80s, is walking down the street when he hears a voice crying, "Pick me up, pick me up." Looking around and finding no source for the voice, he walks on. But then the voice returns, and he spots a large green frog, its mouth forming the words. He picks up the frog and holds it in his palm as the frog explains: "I am a beautiful young woman, turned into a frog by a wicked witch. But a kiss from you will restore me. Do this, and I will be yours to fulfill your deepest desires and sexual fantasies." Having listened, the old man puts the frog in his pocket and walks on. After a few minutes the frog calls out, "So why didn't you kiss me?" The old man replies, "At my age, I'd rather have a talking frog."

In recent years with high-profile media attention given to erectile dysfunction drugs, full body makeovers, anti-aging creams, and memory disorder documentaries (especially those dealing with Alzheimer's disease), an overabundance of jokes have entered the social mainstream, most perpetuating an age-related stereotype. Consider the scene in the 2003 movie

Something's Gotta Give in which actor Jack Nicholson, playing an aging music industry exec with a fondness for young women, has a heart attack while in bed with his trophy girlfriend, Marin, played by Amanda Peet. He is rushed to the hospital and is about to receive a vasodilator drug. When he is asked whether he is taking Viagra, he shakes his head, but when told that the drug interaction could kill him, earnestly shouts, "Yes!"

Positive Humor of the Elderly

Countering the myriad negative jokes about older people, a rising genre of positive humor employed by older people themselves is exemplified in the story told by humor researcher Lucille Nahemow in an important collection of essays, *Humor and Aging*. Nahemow recounts a conversation with a resident of a nursing home who is diligently hemming a square of cloth. Nahemow, out of politeness, complements the woman's work, which, in fact, is rather poorly done. To this the woman replies that she has been a tailor for 60 years. She's just trying to humor an activity director who thinks she is teaching her the art of stitchery.

Certain famous actors have become icons of humor that is expressive of the wit and wisdom of the elderly. Hume Cronin and Jessica Tandy, now both deceased, played elderly characters in numerous films who overcame the prejudices of the young and middle-aged, showing their pluck and capacity for empathy over the ignorant and feckless who saw little value in history, tradition, or its bearers.

Ambivalent Humor about Aging

The 1984 film *Cocoon* captures in its humorous plot certain ambiguous and ambivalent meanings of aging that surface in a growing body of films, novels, and dramas. *Cocoon*'s cast of famous actors play residents of a Florida life-care community who inadvertently stumble on cocoon-like pods resting at the bottom of a swimming pool on an abandoned estate. As the story unfolds, viewers learn that the pods are designed to restore a number of extraterrestrials left on earth from an expedition thousands of years earlier. By swimming in the pool's 'fountain of youth' waters, the human elders' aging process is reversed. Through a series of mishaps, the earthlings are invited to experience eternal life and health if they choose to return with the extraterrestrials to their planet. Despite social conventions that would mitigate against abandoning grandchildren and adult children and foregoing their earthbound responsibilities and the traditional piety of accepting the inevitability of death, the cluster of friends choose literal immortality and head off toward other galaxies. The film is a lightly veiled allegory of the mixed blessings of the powers of life-sustaining medical technologies, uncertainties about the promised resurrection of the body and afterlife of the soul promised by mainstream religions, and fantasies of prolongevity sometimes prophesized by geneticists and molecular biologists.

Four Contemporary Aspects of Humor and Aging

Four important aspects of aging-related humor have emerged since the 1970s: (1) a new image of the elderly in popular culture, (2) humor therapy, (3) humor scholarship, and (4) developmental approaches to humor and aging.

Older People in Popular Media

We have already cited several films in which mature adults serve as protagonists. To these we may add a host of films characterized by a theme that film scholar Charles Nicholas calls the 'elderquest.' Movies such as *The Trip to Bountiful* (1985), *The Straight Story* (1999), and *About Schmidt* (2003) center on an older person's metaphorical and literal journey, whether to a childhood hometown, a sick brother's house, or cross country in a recreational vehicle to a daughter's wedding. Each journey is a personal saga, a search for resolution of some long-simmering conflict, a search for authenticity. The elderquest genre goes back at least to Ingmar Bergman's 1957 classic, *Wild Strawberries*, in which the septuagenarian physician, Isaac Borg, tries to come to terms with painful elements of his past while on a car trip in Sweden to attend an honorary ceremony at the University of Lund.

This motif of return and reconciliation in later life fits well with Erik Erikson's 'eighth stage' of life, in which themes of despair and despondency are juxtaposed with self-acceptance and self-integration, a struggle in which the ideal result is wisdom. Because most of the films have poignant and more or less happy endings, with the protagonist rising above limitations, burdens, and barriers, they qualify as comedic.

Not all films related to later life fit the elderquest theme. The comedy *Grumpy Old Men* (1993), with its curmudgeonly heroes, is meant to be funny, if not plain silly, while the now-classic *Fried Green Tomatoes* (1991; another Jessica Tandy film) adds a feminist angle to lessons of aging passed down to a younger, midlife generation embodied by the dowdy, downtrodden housewife played by Kathy Bates.

Television sitcoms such as *The Golden Girls*, *The Jeffersons*, and even the animated *The Simpsons,* with its nursing home-bound father and grandfather, Abraham Simpson, frequently at the heart of the plot, testify to the prominence of older characters who retain their distinct individuality, eccentricity, and dignity. American newspapers feature numerous elders in comic strips such as *For Better or Worse, Shoe,* and *Lola*. They are sometimes portrayed stereotypically as grumpy, intrusive, disabled, or dithery, but just as often are portrayed as brave, caring, insightful, and wise.

Humor as Therapy

Ever since Norman Cousin's 1976 book, *Anatomy of an Illness*, told the story about how *I Love Lucy* TV episodes and Three Stooges and Marx Brothers films helped the well-known author and journalist recover from a crippling disease, humor's therapeutic value has captured the popular imagination. Countless humor workshops attract people from the corporate world to hospice centers, eager to discover how mirth as an emotional response can help heal, soothe, relieve, strengthen, or motivate. In a 2001 article, Johns Hopkins University School of Nursing professor Ronald Berk summarized eight psychological benefits of humor based on available research: reducing anxiety, reducing tension, reducing stress, reducing depression, improving self-esteem, restoring hope, restoring energy, and providing a sense of empowerment. To this list he added physical benefits such as improving respiration, stimulating circulation, decreasing stress hormones, increasing the immune system, and increasing the production of endorphins, which help to decrease pain by producing a sense of euphoria.

Humor therapeutics have been used in nursing homes to offset depression and even with patients recovering from cataract surgery to speed up the healing process. Humor is also used as a teaching device to communicate with students about sensitive topics such as death, dying, grieving, and suicide.

Humor Scholarship

While one cannot obtain a doctorate in humor, the academic study of humor has proliferated at universities in the United States and abroad through specialized courses, international humor research associations, and journals such as *HUMOR: International Journal of Humor Research*. Further testimony to the productivity of humor scholars are the numerous encyclopedias on American humor, humor in eighteenth, nineteenth, and twentieth century British literature, and humor in Irish literature. There have been numerous academic conferences on humor and aging covering topics ranging from the physiology of laughter to aging comic characters in the late novels of American writers Saul Bellow and Philip Roth.

Humor Viewed Developmentally

Humor is not just a mood, asserted language philosopher Ludwig Wittgenstein, it is a way of looking at the world. Other scholars concur that a person's ability to catch the drift of humorous tales or situations reflects both moral and cognitive developmental stages. Researchers at the University of Toronto's Department of Psychology argued in a 2003 article that they found a clear correlation between cognitive functioning and humor comprehension. This, the authors argued, is important since "affective responsiveness may underlie the success in using humor as a coping mechanism in the elderly."

Curiously, the capacity for producing humorous remarks is observed even in those with mild to moderate dementia. A gerontologist observed the meeting between a cognitively intact sister-in-law and her Alzheimer's disease-afflicted brother-in-law. The woman, reaching out to the brother-in-law from her wheel chair, started to cry. Whereupon the brother-in-law quipped, "Don't cry, Marion. We're still here. Aren't we?"

Countless incidents of ironic humor reflected in mature adults' acceptance of mortality are embodied in this account from another gerontologist observing a committee meeting at a senior center. A tall, tweed-jacketed gentleman rises to give his report on behalf of the long-range planning committee. He clears his throat and announces: "For me, long-range planning means what I'm going to have for breakfast." Such humorous remarks might be classified under the adage 'I don't buy green bananas.'

Although it might not be possible, as gerontologist Mildred Seltzer observed, to convert the humorless of any age, appreciation for humor does seem to deepen and grow more complex as some people age. Greater tolerance of ambiguity and the ability to handle multiple viewpoints and paradoxical life experiences may make one a better humor follower. Those with a great sense of timing may become skilled initiators of humor.

Sigmund Freud recognized humor's positive contribution to mental health. Laughter, Freud asserted, using the early twentieth-century metaphor of the steam engine, is an outlet for psychic or nervous energy. Like a system of pressures, the release valve, laughter, could go off when a person felt that the need to suppress anger or sexual feelings might not be necessary. The energy no longer needed to repress

unruly emotions or unacceptable thoughts would be discharged in the form of laughter. This could be accomplished, Freud said, in three ways: through jokes or witticisms, by means of the comic, or through humor. Jokes are usually made at someone else's expense. The comic often involves our pleasure at watching someone who we perceive as inferior, such as the 'tramp' Chaplin, the trio of Stooges, or the *schlemiel* so often portrayed in Woody Allen films. Sometimes we enjoy our sense of superiority over the fool or bumbling character. Sometimes we identify with these characters when they triumph over the attempted domination of the snobbish, intimidating, or authoritarian.

For Freud, the third form, humor, is a different sort because it has a liberating element that makes it both "fine and elevating." Humor is a way of looking at ourselves that expresses the "triumph of narcissism, the ego's victorious assertion of its own invulnerability." To Freud, humor is not a statement of resignation, but a bolt of rebelliousness. Humor rejects the necessity of suffering and, through a shift of perspective, enables one to attain or retain a sense of personal dignity.

Freud's account of jokes or wit, the comic, and humor suggests a developmental hierarchy: the individual moves from a simpler to a more complex expression of laughter, from the slapstick antics of Larry, Moe, and Curly to the profound irony of the Biblical Sarah's laugh. Does capacity for a humorous perspective on life increase with maturation, or is sense of humor a gift that comes with certain personalities? Freud does not comment, but nineteenth-century Danish philosopher Søren Kierkegaard thought humor was an achieved perspective. He made humor one of his "stages on life's way."

Kierkegaard proposed three 'spheres of existence': the aesthetic, the ethical, and the religious. Each of these 'life attitudes' is shaped by subjectively and qualitatively different experiences of time. Two additional, transitional stages, irony and humor, complete Kierkegaard's developmental theory.

The aesthetic-oriented person, whom Kierkegaard portrays as a young poet or bon vivant, delights in sensuous beauty and the enjoyment of what, today, one might call 'peak' experiences. But such timeless moments are fleeting and lead to disappointment: peaks are exactly that, they lead to valleys. Sobered by such truths, the ironist, an older, wiser, and perhaps slightly jaded individual, steps back from life, adopting an aloof, defensive posture. He or she is not going to be taken in by false hopes and ephemeral thrills. The ironist pretends to be above it all, but that is a lonely position, one that brings despair over the prospect of further development. Eventually, though not always, the ironist accepts life's incongruities and the emptiness of living for shear possibility, and matures into the ethical individual, embracing the enduring value of friendships, marriage, and career. The ethicist, portrayed in Kierkegaard's *Either/Or* by the figure of a judge, is the product of the exhortation 'choose yourself,' and belong to what Kant called the "universally human." While the aesthete dwells in spontaneity and immediacy, the ethicist values reflection and permanence.

Kierkegaard's ethical stage sounds like the achievement of autonomy, frequently regarded as the end stage of moral development. But Kierkegaard argues that the ethical is no stopping point, because people still find an inner urgency caused by the irreconcilability of a yearning for the infinite or eternal while constrained by the finitude of human existence. Kierkegaard is a master of analyzing the condition of despair. In modern popular parlance, a symptom of this longing is commonly expressed by the midlife complaint: "Is this all there is to life?"

Awareness of one's mortality stirs, in some, a spiritual need, the desire to view oneself in a larger context of meaning related to nature, the divine, and the cosmological. The dawning of the religious search is to be at one with the divine. Heralding the transition between the ethical and religious stages, Kierkegaard identifies the intermediate stage of humor, which is a certain type of philosophical outlook characterized by detachment from, yet empathy toward, one's fellow creatures; appreciation for, rather than distress over, the irreconcilable aspects of life; and the realization that the search for meaning will never end, nor will the quest for an illusive sense of completeness.

Kierkegaard insisted that the fulfillment of human development belongs to the religious stage, and not just any religion, but his highly individualistic version of Protestant salvation. Leaving that terminus aside, we note that Kierkegaard was one of the great nineteenth-century thinkers to understand human development as a dialectical process operating well into adulthood. He did not seek to match up the stages of life with specific chronological intervals, but the characters he created to represent these stages suggest that the ethical stage and beyond belong to midlife.

While perhaps not a perfect fit for Kierkegaard's more theological interpretation, still the words of psychologist Florida Scott-Maxwell capture this elevated humor perspective. Writing autobiographically in *The Measure of My Day*, she says: "When a new disability arrives I look about to see if death has come, and I call quietly, 'Death, is that you? Are you there?' So far the disability has answered, 'Don't be silly, it's me.'" Scott-Maxwell shows how the pain of physical decline can be blunted by an attitude of comedic detachment.

Humor, Aging, and Creativity

Koestler on Humor and Creativity

Adding to the appreciation of humor, Arthur Koestler, in *Act of Creation*, saw remarkable similarities between humor and creativity. Scientific discoveries and jokes both involve holding incongruous facts and ideas together in such a way that a new insight may be born. Koestler termed the common element of humor and creativity 'bisociation.' When Einstein climbed aboard a trolley and discovered the analogy he had been seeking for the theory of relativity, one could imagine that Einstein's "aha!" was quickly followed by "ha, ha." Indeed, the laugh of creativity goes back to the Bible.

Biblical Humor and an Elderly Couple

An ancient laugh reaches us from the book of *Genesis*. The primal parents of the Jewish people, Abraham and Sarah, are dwelling in desert tents when three nomadic visitors who are heavenly messengers suddenly show up. Sarah is sitting discretely behind the flap of her tent as one of the messengers tells Abraham that Sarah will soon be with child. This is a remarkable prophecy, since Sarah is a childless 90-year-old and Abraham is nearly 100. A divine voice had already promised Abraham that not only a child but also a whole people would descend from the couple. On that occasion, Abraham had "laughed in his heart." But now, Sarah laughs out loud. The messengers point an accusing finger. How dare she laugh? Sarah denies it, though her doubts are certainly reasonable. Nevertheless, it turns out the angels are right. A few sentences later, the proud parents are naming the child Yitzchak (Isaac), from the Hebrew root meaning 'to laugh.'

For centuries, biblical scholars have argued over Sarah's laugh. Some hear in it the laugh of sarcasm, others that of doubt, ridicule, or incredulity. These interpretations fail to grasp the mythical quality of the story. Through an imaginative leap, the tale links the listener to the story of how God created the world. Sarah and Abraham's laughs echo the creation story: how a world comes forth out of emptiness. The birth of Isaac is a human parallel to the surprise of divine creativity. Sarah's becomes the laugh of joy.

Humor and Wisdom

From the biblical Sarah to the veteran actress Jessica Tandy, the laughter and humor of older people deal with some of the most serious and difficult of subjects: fertility, sexuality, birth, family, aging, death, and wisdom. Seniors' humor teaches us that laughter is a basic human response and humor a natural way of coping.

The first century Jewish historian Philo grasped the connection. "If someone has experienced the wisdom that can only be heard from oneself, learned from oneself, and created from oneself, he does not merely participate in laughter: he becomes laughter itself." Achieving enlightened laughter may not be possible for everyone, but when one hears the laugh of the wisely old, one can at least listen and search for smiles of his or her own.

See also: Ageism and Discrimination; Images of Aging; Literary Representation of Aging.

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Images of Aging

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Glossary

Ageism – Discrimination against individuals or groups because of their age.

Consumer Culture – The culture of the consumer society with its images of youth, fitness, and beauty.

Images – Visual representations of the external appearance of the human body.

Mask of Aging – The experience of a disjunction between the aging body and the 'ageless' self.

Social Constructionism – The view that aging is not a biological given, but is constructed by society.

Stereotypes – Oversimplified public images that are often stigmatizing.

Introduction

Gerontological interest in the analysis of visual images of the aging body and the role images play in constructing the meaning of the aging process is of comparatively recent origin. It can be traced back to the mid-1960s, when it emerged as the result of two major social developments. The first was the belief that one of the most urgent problems facing societies with increasing numbers of older people was that of ageism, a term that refers to the widespread existence of negative attitudes toward people simply because they are biologically older. Analyses of the images of old age in, for example, greeting cards, comic strips, and the movies showed that older people were consistently represented in a negative manner. The second development was the greater awareness of the key role played by visual images in the construction of social life. It is often observed that contemporary Western societies are consumer societies and that the construction and dissemination of visual images is a central feature of consumer culture. Technological innovations in the means of producing and communicating visual images have resulted in a massive expansion in the volume and realistic quality of visual images that can be communicated to audiences. Recurrent themes in consumer culture imagery are youthfulness and beauty alongside a negative depiction of aging and old age.

It is now widely accepted that the quality of life of the increasing population of older people will be considerably enhanced by the elimination of negative images or stereotypes of the aging body as a body in decline and their replacement with positive images of old age as an extended phase of active life. This quest is built on the assumption that the images that circulate in public work in two ways. First, public images are considered to both reflect and shape social attitudes toward older people and the treatment they receive. Second, public images influence individual perceptions of the self and the construction of personal identity in later life. The personal meanings of old age are the result of the reflection by each individual upon the public images of later life with which he or she becomes familiar. Public images are a key resource for making sense of the biological processes of aging which are exposed to public scrutiny because they are evident on the external surfaces of the human body. Wrinkles on the face may, for example, be interpreted either positively – as signs of a life experienced to the full – or negatively – as signs of failure and regret.

It is now, therefore, accepted that images operate in flexible ways: their meanings exist on several levels and they are always open to a wide variety of interpretations, especially in contemporary Western societies. This perception arises from recent developments in the study of culture and mass communications that have shown that the relationship between image and audience is essentially a dynamic one: audiences can no longer be seen as made up of 'cultural dopes' who can be easily manipulated by the image makers. Mass communications may best be understood as performances, resulting from

processes of interaction between image and audience whereby viewers respond to the images (e.g., television or movies) before them according to their specific interests and cultural allegiances. For this reason, gerontologists are becoming aware of the diversity of images of aging that circulate in multicultural societies. They are also becoming aware of the ways in which images of aging are being actively transformed as the result of technological innovations in communication systems (photography, movies, television, video, and computing).

The images of aging now emerging in contemporary Western cultures are, therefore, becoming much more complex and fluid. Good examples of the development of new images alongside older stereotypes can be found in advertisements for goods and services for the expanding section of the population in the 50 plus age group. Advertisers are coming to appreciate the value of associating images of these consumer products (fashions for the over 50s, cosmetics, retirement homes, vacations, educational opportunities, labor-saving devices) with images of youthful bodies in middle and later life. Biological aging is thus constructed as a period of continuing physical health and activity in opposition to the stereotyped image of middle and later life as a period of diminishing energy and disengagement. Associations between the body in a state of physical decline and rocking chairs, slippers, and drowsiness are replaced with images of continuing bodily activity and vigorous social encounters. What is interesting is that these new images, designed to revise and even revolutionize middle and later life, are also images of age-related retirement and leisure and, given this essential ambiguity, open to a more flexible range of interpretations than the comparatively more rigid older representations of life after 50 as inevitably a one-way status passage to old age and death.

The Role of Images in Social Life

Background

From the moment of birth human bodies are biologically programmed to age and die. The effects of this program are visibly displayed on the human face and body. This means that every time one looks at a human being, or an image of a human being in, for example, a painting or a photograph, one perceives an individual who can be identified in terms of his or her age. In biographical accounts of the lives of famous people, paintings or photographs of these individuals when they are older are often identified with the words in old age or as an old man/woman. Because all humans are part of a process of biological growth and decline, and this process is visibly displayed on the face and body, every image of the human face and body is necessarily an image of aging. But human beings do not only exist in a biological lifetime, running from birth to death; they also exist in historical and cultural time. Images of the body are constructed out of the visual images and language available at any particular time in history and in any particular culture. It is because human beings use images, both visual and verbal, to construct social life and give it meaning that they are more than simply biological bodies. But it is also important to note that the relationship between images of the body and the personal experience of the body is complex and is determined by people's lived experience in a variety of cultural contexts. The meanings of images of the aging body, whether they are found in drawings, paintings, photographs, movies, TV programs, or videos, are culturally coded and yet at the same time open to a wide variety of interpretations depending upon the situations in which they are encountered. In some cultures, for example, the wrinkles on an old person's face are viewed with ridicule or disgust, whereas in other cultures they may go unnoticed or even be seen as a sign of higher status. Images of the aging body, therefore, can be used to convey either positive or negative messages, and these messages can powerfully influence the ways in which younger people relate to older people and older people relate to each other.

Although visual images have emerged as the most influential form of mass communication, it must be remembered that they can never be completely separated from language. When looking at a visual image (a caricature of an old person, a photograph of an older man or woman in a biography or in a family photograph album) the understanding of its meaning is necessarily in terms of the categories or typifications made available through language: for example, the language category 'old man' or 'old woman.' Yet at the same time, images are never wholly reducible to language, and it should be recognized that much of social life (and this has been increasingly the case since the development of consumer culture in the nineteenth century) takes place within the visual field. The study of visual images of aging, therefore, requires an acknowledgment of the dynamic relationship between visual representations and language.

Definitions

In everyday terminology, an image is often regarded as an accurate representation of an object or person. As far as images of human beings are concerned there is a tendency to see the body as something that because of its material (embodied) existence can easily be copied or represented. The notion of copying and

producing an accurate likeness of an original in a variety of media (the sculpted portrait bust of Benjamin Franklin is another good example) is one of the key meanings of the term image which can be traced back to the original Latin meaning of the *imago*.

But the term image also has an important second meaning, and this is derived from associations with the role of the imagination and the imaginary. In this second meaning, the emphasis is not on the accurate representation of an independently existing objective reality, but on the power of the imagination to construct and shape an image of reality. There is an interdependency between the image as it is recorded and the imagination of the viewer. From this perspective, images are regarded as playing an active role in the social construction of reality. Reality is understood to be more of an imaginative projection than an object existing independently of the viewer or society. Just as images have an important part to play in the construction of the body, they are also seen as making a significant contribution to the social construction of the self. The self, grounded as it is in the body – or embodied – is thus a product of social interaction. A good example can again be taken from the use of photography. Debates about the accuracy of photographs of family members are a commonplace feature of everyday life, and people often have some difficulty in recognizing their own photographs as accurate images of their 'real' selves, especially when the photographs were taken several years ago.

The second meaning of the word image, therefore, refers to the original definition of photography as painting with light. It suggests that an image is essentially produced through an interpretative act whereby the subject's body is clothed and adorned in particular ways and framed in a setting of material objects, all of these carrying a specific symbolic value, emotional tone, and resonance. The image is, then, a social construction that frames a world in order to make sense of a vast array of sensory stimuli. As a photograph relates to a specific point in the lifetime of a person and his or her relations to other persons at that time, it carries hidden significances and emotional charges that are themselves unstable, altering with the changing vicissitudes of the person's subsequent experience. It is also open to changing interpretations of history, as in the case of recent analyses of Victorian photography and, in particular, sociological analyses of photographs of older people taken during the closing decades of the nineteenth century. This research shows, for example, how photographs of old people living and working in rural areas of Scotland are not 'natural' images but socially constructed compositions deliberately framed to reflect current social beliefs about the simplicity and integrity of country life.

Images and Stereotypes

An appreciation of the complexities of images and the theorization of their role in the social construction of reality is now influencing research into the social stereotypes of aging and old age. The word stereotype is derived from the Greek *stereos*, meaning form or solid, and *typos*, meaning an impression or model. The process of stereotyping is one in which the subtle differences and nuances that distinguish one individual older person from another are dissolved in order to transform aging into one uniform process. Stereotypes of old men and old women are often regarded as displeasing and offensive by older people because they convey the impression that individual differences and distinctions are somehow dissolved or destroyed by biological age. Moreover the stereotyping of old age as a single uniform process with similar effects on all older people regardless of culture, gender, time, and place, is seen as having a negative effect on the quality of later life precisely because public images of old age in Western culture have tended to focus on its negative aspects. In general, the stereotype old is a social category that implies that every old person is not eligible for full acceptance in social life. One of the clearest examples of the stigma of aging is age discrimination in employment in which people over a certain age are barred from applying or are dismissed. Such barriers may, of course, exist only in the form of unwritten rules or understandings that are never explicitly advertised but their ultimate reference point is an image of older age as a social stigma (*see* Ageism and Discrimination).

At the same time it must be remembered that the effects of stereotypes of aging are not always as clear cut as is sometimes imagined. Not all stereotypes of old age are negative, and stereotypes of aging are often highly ambiguous precisely because old age is not experienced as a single uniform condition. Yet, because the basic social function of stereotypes is to make sense of complex experiences and to reduce tangled patterns of information into an easily communicable set of images, there is a strong possibility that stereotypes may give highly misleading messages to the wider public. A good example is that of the grandfather and grandmother whose popular image is that of gentle, socially disengaged, and desexualized men and women with white hair and ready smiles who dote continuously upon their grandchildren – figures, moreover, who are often White and middle class. The fact that large numbers of

grandparents in Western societies are in their 40s and 50s means that real-life grandparents have an image problem. In this context it is interesting to note that a number of popular magazines have come into existence to cater to a new generation of grandparents who do not identify with this stereotypical image.

Further evidence of the misleading stereotyping of the aging process involves the binary distinction between images of youth, usually represented in Western stereotypes as the most active and desirable phase of life, and images of old age as a period of decline and decay, one that is at best a preparatory stage for death and the afterlife. A typical historical example can be found in an engraving by Jorg Breu the Younger published in Augsburg in 1540. Entitled "The Ten Ages of Man," it displays life as a series of steps leading first of all progressively upward from birth through youth to the high point of middle age (what is often described as growing up) and then, in the second major phase, stepping inexorably downward through old age toward death and finally the afterlife (what is often described as growing old). In this compelling image, which has for centuries exercised a pervasive influence over the Western imagination, the life course of every individual is structured in terms of series of predetermined steps that he or she must follow. It is an inflexible image and it does not, therefore, allow any possibility of alternative interpretation.

As a characteristic example of the ages of man tradition that continued to stereotype the life cycle well into the nineteenth century, Breu's engraving confirms a clear relationship between old age and decrepitude. The final stage of life in the material world is represented in the image of a bowed and bearded old man, as one of fatigue, invalidity, and preparation for death.

Prior to the seventeenth century, Western images of life as a series of ages represented life in masculine terms. The images of the ages of life were images of men. But during the seventeenth century artists began to draw distinctions between the typical stages of the life of man and the stages of life of woman, the ages of woman being defined in terms of virtuous domesticity. Prescribed models of the ages of woman display the same upward progression to the peak of middle age, followed by a series of steps or stages downward to a bedridden old age, death and immortality. In all these images, the virtuous – whether male or female – are rewarded with a heavenly afterlife, and the vicious are punished in hell. Such images continue to influence stereotypes of the life course in present-day society, the only significant difference being the absence of an explicitly religious cosmology.

Breu's work is a typical example of the social construction of stereotypes of old age in order to prescribe moral distinctions between virtuous and vicious aging. The boundaries between the ages of life that constitute the life course and the boundaries between positive (moral) and negative (immoral) aging are rigidly defined. This practice has a long history in Western culture and can be traced as far back as classical antiquity with a line of continuity stretching up to the present day. Art historians have shown, for example, in seventeenth-century Holland, how stereotyped images of older men and women were used to depict the moral message of the rewards of the virtuous life for men and women alike. Paintings of avaricious and lewd old men and women stand in deliberate contrast to images of virtuous merchants, craftsmen, and housewives who diligently carry out their gendered duties in expectation of a reward in the next world. The division of labor between men and women is clear but the moral stereotyping of aging as a journey of life is the same for both.

Similarly, in nineteenth-century painting, there is a pronounced tendency to represent the idealized form of old age as a final stage of dedicated domestic seclusion, frequently against the backdrop of a rural environment. In addition to framing the potentially threatening physical decline of old age within a comforting domestic setting, such images also reflect nostalgia for a disappearing rural life in a society undergoing rapid modernization with its attendant urbanization and expanding consumer culture. Such nostalgia involves a dual repression of the complexities and often harsh nature of rural life and the realities of growing old in a world where competitive individualism was placing an even higher value on the active physical body. Increasingly in the nineteenth century, images of old age reflected a moral distinction between those who aged well, that is, preserved their independence to their last breath, and those who aged badly or gave in and became dependent on others.

The same process of binary stereotyping occurs in the case of portraiture, an art form whose ostensible purpose since the Renaissance has been the representation of the visible appearance of individual character as revealed in the face and bodily comportment. Yet even when artists set out to paint a portrait of an identifiable individual who has attained old age, their efforts often incorporate elements of stereotypical conventions concerning a 'good' (or morally worthy) and a 'bad' (or socially deviant) old age.

The more general point to be made, therefore, is that images of old age should often be viewed not so much as descriptions or documentary records of the

actual historical conditions of older people, but as prescriptive social texts. Art historians often emphasize the distance that can be assumed to exist between, for example, the prolific images of old age in paintings that were produced in The Netherlands during the Golden Age of the seventeenth century and the everyday lives of those relatively small numbers of men and women who actually lived long enough to experience old age. These images should be viewed as reflections of the beliefs and traditional conventions governing the pictorial representation of older people as social types. Good examples are the inappropriately amorous old woman in a brothel and the rich old man who foolishly married a young wife and who, for the amusement of the audience, is being conspicously cuckolded.

The imaging of old age as a symbol of social or political virtue can be traced back to the sculpted portrait busts of prominent figures in classical antiquity. At one period in the history of ancient Rome, from the second century BC to the sixth century AD, portrait busts of elder statesmen were sculpted to give explicit facial expression to idealized political virtues. The signs of aging were carved into these in order to give enduring form to the public virtues of long service and stability as perceived in the faces of their living models. As such, they were celebrations of an association between old age and social and political stability, of the perception of a close interrelationship between the virtuously aging individual face and a public life dedicated to duty and self-discipline. This close physiognomic relationship between the public and the private, the inner subjective self and the outer public social identity, was reflected several centuries later in portraits painted by the German artist Albrecht Dürer (1471–1528). The portraits he painted toward the end of his own life of a number of notable converts to the Lutheran religion in Germany have been described as a deliberate attempt to reveal the outward signs of the inner spiritual transformation of men who had been converted to the new religion. It has been argued that Dürer's portrait of Frederick the Wise (1524), who died within 2 months of its completion, was intended to represent the face of an older man who had been restored through religious conversion to a youthfulness of spirit. In both Roman antiquity and sixteenth-century Lutheran Germany such images of the visible appearance of aging were specifically created as icons of exemplary social qualities. As portraits of recognizable individual persons who were growing older, and therefore in this sense images of aging, they are also expressions of predominant social aspirations concerning forms of spiritual growth and development.

Images of old age continue up to the present day to be constructed as moral images or metaphors of social life, symbolizing the beliefs and value of the age. It is the very conventionality of the belief system underlying traditional images of old age – their stereotypical quality – that has ensured their continued influence up to the present day.

At the same time, there are significant signs that a major transformation in the imaging of aging has been slowly emerging since the mid-nineteenth century. One of the most obvious differences between traditional methods of image production (drawings, paintings, etchings, and so on) and those in use today is the emergence of new techniques of image production and reproduction associated with developments in consumer culture. Also radically different are the means of communicating images and distributing them to a mass audience. Since the nineteenth century, innovations in photography, film, television, and video have vastly increased the number of images in circulation. Moreover, the need to find outlets for mass-produced goods resulted in the proliferation of department stores, shopping malls, and arcades and in the development of visually sophisticated advertising techniques. These processes of mass marketing helped to produce the consumer culture 'dream worlds' in which it became possible to attach a whole range of romantic and exotic imagery to mundane goods. Since the mid-nineteenth century, therefore, goods have been increasingly advertised in terms of their value in enhancing the lifestyle of the purchaser. They are no longer bought simply because they satisfy basic human needs such as hunger, warmth, and shelter. Consumer goods should not be regarded as solely material things, but as containing a strong symbolic component. In effect they act as communicators that engage the admiration, approval, and envy of others. In this context it is the emphasis on the shift from the producing to the consuming body that has a crucial significance for images of aging.

In a world facing for the first time in human history the global prospect of an aging population, the image-saturated consumer culture constantly valorizes bodies that epitomize youthful energy, fitness, and activity. There is a tendency to present bodies, social relationships, and lifestyles as things that need working at, things which can be reshaped and renewed. Indeed the need to combat a fateful sense of bodily fixity and decline is often presented as a moral duty. The result is a foreground of age consciousness and an ageist rejection or denial of the biological decline of later life. Unlike the traditional images of the ages of man and of woman, contemporary images of the life course attempt to eliminate the

downhill stages to death and the after life and to replace them with an extended plateau of middle life. Ironically enough, the virtuous response to growing older, portrayed as an essentially spiritual acceptance of physical decline and the inevitability of death that we saw in the traditional iconography of aging, is now located in the celebration of resistance to aging and the rejection of old age. In contrast, to age negatively is to let oneself go – in effect, to abandon the struggle to maintain a youthful appearance and lifestyle.

This rejection of the physical realities of old age in favor of images of a perpetual state of middle age both reflects and gives expression to the ambiguities and uncertainties which increasingly surround old age in contemporary society. As the population of older people expands, particularly the proportion of people aged 70 and over, evidence from empirical research into the everyday lives of older people clearly suggests that the actual experiences of old age are much more varied and often much more positive than ageist stereotypes imply. Even when suffering from ill health or a serious physical disability, many older people continue to enjoy independent and fulfilling lives. These findings lend further support to the argument that many of the negative aspects of aging are not biologically or chronologically determined. Rather, they can be shown to be the result of the meaning that individuals give to the aging process in later life. The images they draw upon to construct these positive meanings are therefore of great significance.

It should also be emphasized that the largest proportion of people in the age category 75 plus are women. It is now important to construct images of aging that represent the predominance of women in this category and give much greater prominence to positive images of women in later life. This task is seen as particularly important because it is increasingly acknowledged that women suffer from the double jeopardy of ageism and sexism.

Interest in images of aging has gradually increased among gerontologists and professional groups working on behalf of older people throughout the Western world. In the United States, the Gray Panthers, the National Coalition on Aging, and the AARP battle to reverse ageist stereotypes of older people as socially dependent and disengaged members of the population. Increasing publicity has also been given in recent years to the positive contribution older people make to social life. The basic assumption here is social constructionist. Older people have unjustly been subjected to the harmful effects of negative stereotypes, and those concerned with promoting the interests of older people in the context of an aging world must learn to construct and deploy a new multicultural positive imagery of old age.

At the present time there is a strong tendency for the positive images of aging that have been constructed to counteract negative stereotypes to overemphasize the qualities of youthfulness and as a result to foster a sense of disjunction between the body and the self. Those old people whose bodily appearance does not conform to the youthful stereotype of aging (i.e., whose bodies visibly display the physical signs of aging – wrinkling, hair loss, graying of the hair, reduced flexibility and mobility, impairment of sight and hearing) often express the feeling of being trapped within an aging body. This sense of entrapment has been described as the mask of aging, a term that refers to the ways in which the aging body can no longer express the subjective experience of the inner self. The biological body grows older but the inner self appears to be ageless or fixed at some earlier point in the life course. In its most extreme manifestation, the case of Alzheimer's disease, one of the most distressing experiences of both caregivers and sufferers is that of an essentially youthful inner self relentlessly imprisoned within an old and decaying body. The predominant image here is that of a dualistic contest between two opposing forces: the biological body and the subjective self (*see* Dementia).

Images of Aging in a Multicultural World

There are two significant indications of the potential for expanding the range of positive images of aging that are of increasing interest to gerontologists. The first is the growing awareness of a multicultural world. The second is the realization that scientific discoveries and technical innovations have far-reaching consequences for the aging process.

Awareness that we live in a world characterized by multicultural variations is displacing the older sociological view of people bonded together through a common culture with its shared beliefs and values. It is becoming apparent that societies consist of a diversity of cultural groups often engaged in struggles for equality and respect. Among these are ethnic groups and groups of disabled people. Although it is now recognized that biological aging as such is not a unifying force as far as older people are concerned, it is also the case that potentially powerful groups of older people do exist and show signs of becoming increasingly conscious of their social position.

In the not-too-distant past when images of aging were collected for display at conferences and exhibitions or as illustrations in books and journals, there was often a tendency to present oversimplified and sometimes romantic images of old age. The

predominant image of aging was very often White and middle class, excluding a wide range of other social groups. References to variations in attitudes to aging according to socioeconomic status (SES), ethnic background, and gender tended to be glossed over. Since the late 1980s, however, gerontologists have paid much more attention to class, gender, regional, and ethnic differences.

A useful example is the image of old age as a time of infantilization, as a second childhood. Because Western culture places such a strong emphasis on mature adulthood, there has been an emphasis on the traditional model of the life course for both childhood and old age to be represented as protected and dependent stages of less than full adult status. This continues to be reflected today in the treatment of older people as if they are dependent children, especially by professional caregivers in institutions. Ageism can therefore operate through the dominance of images of dependency that take away the adult status and personhood of the elderly. For many gerontologists and members of interest groups concerned with the rights of older people, infantilizing images of older people must be contested and displaced.

Today, however, the negative image of old age as a second childhood is being reappraised. In Japan, for example, once an individual is past the age of 60, he or she is assumed to have completed the first cycle of life and to have entered another cycle in which childish and mischievous behavior is not only expected but looked upon with affection. In Japan older people may be perceived as 'cute,' and as such the recipients of affection from young people, an example being the centenarian twins Kin and Gin, who became media celebrities. In such a cultural context the wrinkles, graying hair, and slurring speech may be ignored, and even perceived positively as signs that older people have attained a state of grace and are nearer to God and the next world. Respect for the outward physical signs of biological aging, expressed in the form of positive images of the second childhood, is an indication of the filial pietism and paternalism that conditions the treatment of older people in Japan.

Any consideration of multiculturalism and therefore diverse and sometimes competing images of aging alerts us to the danger of pushing the parallel between ageism, racism, and sexism too far. Although race and gender continue to be constituted as master categories (relatively unambiguous social categories that entail discrimination and power deficits for the outsider group), such a division is by no means so clear-cut with reference to images of older people and their relationships with the young and middle aged. Unlike the social oppositions of race and gender, youth, middle, and old age are essentially transitional statuses within a universal process of biological aging. As transitional statuses they are reshaped by cultural change. The move toward cultural diversity indicates a richer repertoire of images of aging in the forseeable future. There are signs of this already: traditional groups of elders whose lives and attitudes toward aging reflect earlier twentieth-century expectations are being displaced by new generations of the young old, third agers, aging gays, and many others. A stage in social life has been reached where traditional images, although most certainly of historical and sociological interest, no longer seem relevant.

This view of a rapidly emerging cultural disjunction between even the immediate past, the present, and the future is reinforced by the second significant social transformation. This is the effect of scientific research into the aging process and technological innovations.

The interaction between biology and culture, reflected in studies of the social effects of images of aging, means that human beings are essentially unfinished creatures. Human bodies and experiences of human bodies change with innovations in organ replacement surgery, plastic surgery, and genetic engineering. Such developments are inevitably reflexive: they feed back into the actual experiences of being human. It is now accepted that it is possible to intervene in several of the life processes, including some associated with aging, and to create, so to speak, new human bodies from old. It is therefore possible to identify three developments that will influence images of aging in the future. The first is the capacity to change and modify the external appearance and thus control the image of the aging body. Significantly, plastic surgery now penetrates deeper and deeper below the surface of the skin to sculpt the very structural framework of the body. The second is the ability to reconstruct the inner body by repairing or replacing damaged or decayed body parts. Scientific research is currently on the point of understanding the process of cellular aging so that the 'natural' process of decline can be halted or even reversed. This third development entails not so much the repair of the body, but a mode of escape from its confines. Developments in information technology offer the prospect of the construction of cyberspace and virtual reality. This will allow people with sensory impairment and limited mobility the capacity to move freely in highly realistic simulated environments that engage the full range of human senses and offer an enhanced capacity for interaction with others on a more equal basis. A human body

damaged or reduced by the aging process may no longer need to represent a prison to the inner self.

The potential of these technological developments coupled with our increasing sensitivity to multiculturalism and global diversity holds out the prospect of a more complex and differentiated set of images of aging in the future. It is clear that there is not one essential process of aging but many. It is also clear that to make sense of these social transformations in the future, we will need not one gerontology, since the subject of gerontology is becoming so diverse, but many.

See also: Ageism and Discrimination; Dementia.

Further Reading

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Immune System

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Glossary

Dysfunctional T Cells – Memory cells with a diminished ability to secrete interferon-y after specific antigen stimulation.

Immunosenescence – Progressive decline in immune function that develops with age.

Innate Immunity (also called natural immunity) – Immunity that does not require prior antigenic sensitization.

T cells (also called memory cells) – Cells that have previously been exposed to an antigen and then play a role in long term immunity to that substance.

Introduction

There is a decline in immunity with age. Of all the cellular elements that comprise the immune system, T cells are most affected by age. This may be linked to a relentless and universally occurring age-associated atrophy of the thymus gland and resultant shrinkage of the naive T cell compartment. As T cells are both effectors and regulators of the composite immune response, the age effects can be observed with both antibody-mediated and cellular immune

responses. However, the decline in immune function due to aging (immune senescence) is insufficient to explain the extent of immune deficiency seen in most elderly. Various secondary causes, including poor nutrition, comorbid diseases, diminished integrity of organ systems, medications, social isolation, and physical inactivity, contribute to the commonly observed immune dysfunction. Nutritional supplementation and vaccination are the cornerstones of immune reconstitution, and there may be benefit from exercise, but this remains controversial.

Immune function is essential for the life of all mammals. Abnormalities in immune function are related to increased incidence of infections and worsened outcomes from seemingly unrelated diseases, such as diabetes, Alzheimer's disease, and atherosclerosis. Also, deficiencies in immune regulation can lead to autoimmune diseases and malignancies.

The immune system undergoes various insults throughout life, and as a result there are adaptive and maladaptive changes, ranging from involution of the thymus gland to alteration in functions of T and B lymphocytes. Some aspects of the immune system, such as adaptive immunity, are affected more than others.

These changes, termed immunosenescence, are seen in all elderly, including the healthiest aging population. Immunosenescence has been causally linked to three major health consequences: increased infections, autoimmunity, and failing immune surveillance, which may lead to cancer. Current evidence suggests that such decline in immune function is generally mild in nature. However, there are several secondary causes that weaken the immune system further, such as poor nutrition, comorbid disease, and medications, as well as changes in structure and function of various organ systems.

Immunosenescence

Immunosenescence is a term applied to the progressive decline in immune function that develops with age. The immune system can be divided into two major compartments: innate and adaptive. Innate immunity is conferred by neutrophils, monocyte-macrophage, and NK (natural killer) cells and does not require prior exposure to effect function. Adaptive immunity confers protection against specific antigens. T cells and B cells are essential components of the adaptive immune response. Much research has focused on adaptive immunity and T cell function in the context of aging.

Adaptive Immunity

It has been demonstrated that even at the most advanced ages, total lymphocyte count and the percentage of T and B cells remain relatively unchanged. Though a decrease in lymphocyte count is associated with increased mortality, it is not an age-related change.

Cellular Immunity

Major change occurs in the thymus gland with age. The gland itself undergoes a well-defined involution, with almost complete replacement by fibrous tissue by 60 years of age, with a corresponding decline in the appearance of detectable thymic peptides in the peripheral blood. The thymus gland provides the microenvironment for maturation of naive T cells, and with a reduction of these there is a relative expansion of committed (memory) T cells. Memory cells are those that have been previously exposed to antigen (a foreign substance, usually protein), and they play a role in long-term immunity to that substance. These memory cells cannot act against any other antigen(s). The memory T cells seen in the elderly may be of less proliferative capacity and directed at only the most specific of antigens (oligoclonal), and thus aged T cells, although quantitatively normal, are said to have less antigenic variability. Output of naive T cells is important to keep the antigenic repertoire broad. A large repertoire means a greater variety of T cell receptors (TCRs) that can specifically bind to a wide variety of antigens. With a limited supply of naive T cells in older adults, this repertoire shrinks and susceptibility to novel antigens increases.

Proliferation of T lymphocytes in response to nonspecific mitogens and specific antigens is decreased in the elderly. Interleukin-2 (IL-2) is an important cytokine that promotes T cell proliferation. Decreased numbers of IL-2-secreting cells, decreased blood levels of IL-2, as well as decreased IL-2 receptors and IL-2 receptor-specific mRNA have been demonstrated in cells from old donors.

T lymphocytes can be divided into two broad categories based on the appearance of characteristic proteins on their surface: CD4+ (T helper [Th]) and CD8+ (cytotoxic) cells. Both CD4+ and CD8+ cell populations demonstrate expansion by memory cells with advancing age and a relative reciprocal decline in naive cells. It is known that naive cells are more potent producers of IL-2 and so the diminished IL-2 levels, and, thus, the diminished IL-2 response described with aging may be thereby explained. The Th cells are further classified as Th_1 and Th_2 based on the cytokines produced. Th_1 cells produce IL-2, IL-12, and interferon-γ, and they promote cellular immunity. On the other hand, Th_2 cells produce IL-4, IL-5, IL-6, and IL-10 and promote humoral

(antibody) immunity. There is a shift in helper T cells from Th_1 to Th_2 with advancing age. This may underlie decreased cellular immunity seen with age. Delayed type hypersensitivity (DTH), a function of cellular immunity, is also decreased with age, and this is witnessed by reduced skin test reactivity. As DTH is responsible for controlling and eradicating intracellular pathogens, increased reactivation tuberculosis and herpes zoster, which are caused by intracellular pathogens, are seen with age.

Another striking feature of the aging immune system is an accumulation of dysfunctional T cells. A greater proportion of cytomegalovirus (CMV)-specific clonal expansion of CD8 cells is seen in the elderly. These cells are memory cells, and they are dysfunctional because of diminished ability to secrete interferon-γ after specific antigen stimulation.

Aging is also associated with accumulation of cellular damage caused by oxidative stress produced by aerobic metabolism within cells. Such oxidative stress leads to peroxidation and altered fluidity of the cellular membranes. Because the cell membranes are important components in signal transduction, a decline is observed in cell activation. For example, lymphocytes from older donors have measurable defects in the calcium signaling cascade. Such defects combined with lower synthesis of, and response to, interleukin-2 lead to poor proliferation of T cells. Fewer T cells from older humans progress through the cell cycle after activation, and even fewer cells then re-enter the cell cycle to continue proliferation.

Humoral Immunity

Humoral immunity is a function of B cells. Circulating B cell numbers remain constant throughout the life span. However, there are subtle changes in the site of production. New B cells are generated in bone marrow. However, in aged animals an increased proportion of peripheral B cells is generated from self-renewing clones of CD5+ marginal zone cells. In fact, the proportion of marginal zone B cells increases from 5% in young mice to 30% in older mice. As antibody repertoire depends on somatic hypermutation in new B cells generated in bone marrow and not on clonal expansion of marginal zone type cells, there is a shrinkage in antibody repertoire.

The levels of IgG and IgA may be elevated, while the levels of IgM typically are constant with age. Although the total amount of immunoglobulins are thus normal or slightly elevated, declines in specific antibody titers are noted. Also, in old animals, antibody production with low affinity for antigens is observed, which would further undermine the immune response. General characteristics of humoral immunity in the elderly include a longer time to development of peak antibody titers, a lower level of the peak titer, and a more rapid decline after immunization. Clinically, these changes in humoral immunity are evident by poor responses to vaccines as well as increased infections by infectious agents.

The dysregulation of immune responses, discussed previously, also accounts for the inappropriate appearance of antibodies to self-antigens (autoantibodies). Organ-specific antibodies, such as antithyroglobulin and antiparietal cell antibodies as well as non-organ-specific autoantibodies (e.g., antinuclear antibody [ANA] and rheumatoid factor [RF]), appear more commonly with advanced age. Circulating immune complexes may also increase with age. Curiously, the presence of these markers of dysregulated humoral immunity has less clinical significance in older patients. For example, young individuals found to have ANA are more likely to have associated illnesses, such as systemic lupus erythematosus, compared with older individuals with the same level of ANA.

Innate Immunity

Innate immunity, also termed natural immunity, does not require prior antigenic sensitization. Neutrophils, macrophages, and natural killer (NK) cells form the cellular component of innate immunity. The protective efficacy of these cells depends on their numbers, endothelial adherence, chemotaxis, and phagocytosis.

The number of neutrophils remains constant with increasing age, and so does the proliferative capacity of neutrophils in response to growth factors (e.g., CSF-GM and IL-3). However, neutrophil proliferation can be challenged under severe and persistent infection, which may overwhelm the proliferative capacity and result in neutropenia. Although *in vitro* immune function is relatively unaffected by age, fewer neutrophils arrive at the site of skin wounds in older people. Also, an age-related reduction in phagocytic capacity is observed. This reduction in phagocytic activity is thought to be due to decreased number of microbes ingested rather than a reduction in number of phagocytosing neutrophils.

Absolute numbers of macrophages remains unaffected by age. However, more macrophages are required to elicit optimal T cell response to a mitogen. Upon stimulation by interferon-γ, aged macrophages have reduced capacity to upregulate MHC class II molecules. Such decreased expression of MHC II molecules coupled with reduced interferon-γ signals

from T lymphocytes can undermine antigen presenter function of macrophages.

It is generally agreed that NK (natural killer or large granular lymphocytes) cell function remains unchanged with age, but NK cells increase in number, and so their activity on a per cell basis is though to be reduced with advancing age. In general it is believed that NK cells from elderly donors have defective response to cytokines with a limited subsequent capacity to develop lymphokine activated killer cells. Several experiments have shown that dietary supplementation of elemental zinc can significantly reduce age-associated decline in NK cell function, and this may translate to a reduction in infection relapse, highlighting the importance of nutrition for optimal immune function.

Secondary Causes of Immune Dysfunction

Changes seen in the immune system of healthy older people are relatively small. These changes confer a modest increase in the risk of developing infections. However, the observed impact of age on various infections is out of proportion to what might be expected from immunosenescence alone. Various secondary causes are responsible for this.

It is felt that the age-associated wear and tear of various organ systems predisposes the elderly to infections. Prolonged recumbence, along with a poor cough reflex, impaired ciliary function in respiratory epithelium, and impaired swallowing may predispose a frail older individual to pneumonia. A decreased function of alveolar macrophage may further aggravate the condition. Similarly, benign prostatic hypertrophy (BPH), which leads to stasis of urine in males, and the postmenopausal state in females contribute to urinary infections. These changes in addition to indwelling catheters or urinary and/or fecal incontinence may lead to urinary tract infections. Incontinence, poor integrity of skin, and delayed wound healing predispose to skin infections that are harder to treat.

Institutionalized elderly, who are exposed to many antimicrobial agents, develop infections with unusual and resistant organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* spp. (VRE), and multiresistant Gram-negative rods that produce extended spectrum beta-lactamase (ESBL). Such infections are much more difficult to treat. It is important to remember that classic signs of infections may be absent in older people. Subtle changes, including minor changes in mental status or decreased activity, may be the only clinical indicator of underlying infection; more typical signs, such as fever, cough, or painful urination, might very well be absent. Due to slower rates of metabolism, older people may have a lower average body temperature, and fever may not be observed even with serious systemic sepsis. Instead, a change in body temperature is a more reliable indicator for development of pyrexia. It should also be remembered that hypothermia is an ominous sign in this age group. Thus, aggressive management of elderly with early use of potent antimicrobials is advocated by many, but this practice may increase the prevalence of infections with resistant organisms.

Most elderly have two or more coexisting chronic medical conditions and are likely to be receiving prescription medications for them. High blood pressure, diabetes, chronic lung diseases, cardiovascular diseases, cerebrovascular pathology, and various malignancies are commonly observed in the elderly. Analgesics, non-steroidal anti-inflammatory agents, corticosteroids, antithyroid medications, antibiotics, antipsychotics, antidepressants, hypnotics/sedatives, anticonvulsants, antihypertensives, diuretics, histamine blockers, hypoglycemics, and other medications (such as allopurinol) commonly prescribed in old age may suppress the inflammatory immune responses. Thus, both the comorbid illness and its treatment may play a role in diminishing immune function in older people.

Adequate nutrition is needed to maintain immune function. Both macronutrients and micronutrients, including vitamins and essential minerals, especially zinc and selenium, are important in this regard. Poor nutrition is correlated with lower lymphocyte counts. Absolute lymphocyte counts less than 1500 cells/mm^3 correlate with some degree of malnutrition, while a count less than 900 cells/mm^3 is associated with severe malnutrition and immunodeficiency. Malnutrition affects up to half of all patients with dementia, making it a widely prevalent problem. Furthermore, these patients have a fourfold increase in rates of infection. It has also been shown that nutritional intervention in malnourished ambulatory elderly leads to reversal of changes seen in immune function.

Stress and other psychological factors including depression may impair immunity. Social isolation and marital discord impair immune function. Also, it has been shown that chronic stress can impair immunity conferred by the influenza vaccine. Furthermore, improving social contact has been shown to favorably affect immune function by laboratory parameters.

Infections Commonly Seen in Elderly

Influenza

Influenza epidemics are a significant cause of morbidity and mortality in the elderly. Declining immune

function plays an important role in worsened outcomes. It is generally held that humoral immunity is responsible for prevention of influenza, while cell-mediated immunity is responsible for recovery from influenza by clearing the virus. Peak antibody titers, whether due to natural infection or vaccination, decrease with advancing age. Rates of development of protective antibody titers in response to vaccine decrease from over 60% in the young to 30% or less in the elderly. However, immunized elderly, although not absolutely protected, have less severe infections, and thus widespread vaccination programs are enthusiastically endorsed. The vaccine is cost effective, as it decreases the mortality and morbidity burden by two-thirds.

Pneumonia

Infections of the lower respiratory tract are one of the leading causes of morbidity and mortality in the elderly. Pneumonia, commonly observed in the elderly, is responsible for over half a million hospitalizations every year. The mean age of patients requiring hospitalization is over 70 years, and age alone is a risk factor for developing pneumonia. Prolonged recumbence, diminished swallow, and poor ciliary function are important risk factors of pneumonia. Many microorganisms are implicated in the pathogenesis of the diseases, but *Streptococcus pneumoniae* is by far the leading pathogen, with more than half of all cases attributed to it. The 23-valent pneumococcal vaccine is an attempt to contain the infection, especially in the era of multidrug-resistant organisms. The currently available vaccine is relatively weak, particularly in the elderly, and the absolute effectiveness has been questioned. However, it has been shown that there is a significant reduction in pneumococcal bacteremia in recipients of the vaccine, though it may not decrease the rate of infection. The vaccine should be administered to those over 65 years of age, and if they had any dose of vaccine before 65 years of age, a repeat dose should be administered 5 years after the initial dose.

Herpes Zoster

Herpes zoster is caused by varicella zoster virus. The virus resides within the nervous system (in dorsal root ganglia) and is held in check by competent immune function. However, with immune deficiency, such as in patients with cancer, transplant recipients, or those of advanced age, the virus is reactivated and cutaneous infection (shingles) is the result. Complications of zoster infection are more frequently observed in patients who are over 60 years of age, with postherpetic neuralgia being the most common and most disabling of these. A vaccine for zoster has recently been developed, and a recently published, randomized trial of this vaccine decreased the incidence of the disease by half and the incidence of postherpetic neuralgia by two-thirds.

Urinary Tract Infection

Urinary tract infection (UTI) is the most common infection observed in the elderly. Although usually mild and treated on an outpatient basis, UTI may also be responsible for sepsis and hospitalization in many, and even death in some cases. The prevalence of UTI increases from 2% in young women to 10% in women over the age of 65. Also, in males bacteriuria, which is almost non-existent at younger ages, increases to 5% in those over the age of 70 years, with the onset of benign prostatic hypertrophy (BPH). Including asymptomatic bacteriuria, UTI occurs in 25–40% of women and 15–40% of men in long-term care. Many elderly, especially institutionalized individuals, may have colonization of the urinary tract without any symptoms. Asymptomatic bacteriuria has not been shown to deteriorate health status, increase morbidity in terms of quality of life, or lead to renal dysfunction, nor has it been associated with an increase in mortality.

One-third of transfers from nursing homes to acute-care facilities are the result of UTIs. The predominant organism for urinary infection in elderly females in *Escherichia coli,* whether institutionalized or not, while *Proteus mirabilis* is the most common organism in institutionalized males. *Providentia stuartii* is an organism that is virtually found only in institutionalized individuals. Infection with this organism is more likely to be seen in several residents of a facility.

As mentioned previously, typical signs of UTI observed in younger patients (pain upon urination, symptoms of retention or incontinence, and fever) are frequently absent in elderly patients. Usual presentation of urinary infection is seen as classic dysuria, pyelonephritis, urinary retention, or new incontinence and fever with indwelling catheter. Complicating the clinical picture further, when fever occurs in a patient without urinary symptoms but with a positive urine culture, the positive predictive value of such a culture is only 12%, and thus caution should be exercised before attributing fever in these patients to a UTI. Similarly, non-specific functional decline in an older person could possibly reflect a new UTI, but the presence of a positive culture does not make this a certainty.

HIV

The mean age at the diagnosis of infection with the human immune deficiency virus (HIV) has increased

in last decade. Currently, 10–15% of all newly diagnosed cases of HIV occur in patients over 50 years of age, and 2% of all new cases are 65 years or older. Whereas earlier cases in older patients were associated more closely with transfusion risk, now the predominant form of HIV spread is sexual transmission.

Diagnosis and management of HIV infection in older individuals pose a substantial challenge. The diagnosis is less commonly considered and thus is often made later, and prognosis is thereby worsened. Presentation of HIV infection as AIDS-related dementia and neuropathy may be hard to distinguish from other cases of such syndromes based solely on symptoms, and HIV testing is often not employed with older adults. HAART (highly active antiretroviral therapy) has significantly improved outcomes in all age groups, although immunological recovery is less complete in older patients. Another challenge in the treatment of older adults with HIV is increased drug interactions and end organ damage.

Tuberculosis

More than 20% of the cases of tuberculosis occur in adults over the age of 65 years. However, in the cohort of elderly White males, the incidence of tuberculosis is now primarily in this age group (over 65 years), having doubled in 10 years from 29% of cases to 58%. Elderly individuals are four times as likely to develop tuberculosis as their younger counterparts. However, if they are nursing home residents, this risk is increased by an additional threefold.

Finally, with regard to diagnosis, it should be remembered that older people have less adequate delayed type hypersensitivity (defiant cell-mediated immunity), and thus skin tuberculin testing is a less reliable marker of infection, but should still be employed.

Cancer and Immunity

Cancer is a disease of older people; 60% of all cancer occurs after the age of 65 years, and this age group sustains 70% of all cancer mortality. Some have speculated that a decline in immunity is one of the many reasons, if not the most important reason, why cancer incidence increases with age. However, others have pointed to the types of tumors that occur most frequently in the elderly (prostate, colon, lung, breast carcinomas), which are quite distinct from the tumors seen in profoundly immune-deficient states (lymphoma, leukemia, and Kaposi's sarcoma). It is likely that the most important explanation for the increased incidence of cancer in old people has little to do with immunity and more to do with the prolonged time it takes to develop an invasive cancer (e.g., decades for most epithelial tumors). The role of immunosenescence in cancer development is at best questionable.

Immune Reconstitution

Efforts to improve age-reduced immune function have met with only moderate success. However, it should be recalled that the composite immune capacity of an older person is only altered in part because of advanced age. Greater negative impacts are more likely to be effected by the presence of comorbid illness, malnutrition, medications, or physical deconditioning. Nonetheless, the beneficial effects of certain efforts have been clearly demonstrated, whereas others have marginal effects or remain controversial. A brief summary of efforts at immune reconstitution follows below.

Nutritional Supplementation

Importance of adequate nutrition cannot be overemphasized. Assuring overall nutritional adequacy, including the supplementation of micronutrients, is the cornerstone of this approach. Various trials using laboratory indicators of immune function and infection rates have shown benefits of nutritional supplementation. It should, however, be noted that overzealous replacement of any one nutrient can lead to adverse consequences and may create problems with absorption of other nutrients. For example, very large doses of vitamin A can lead to toxicity, but its precursor beta carotene is considerably safer. Excessive zinc supplementation can interfere with iron absorption and lead to iron deficiency and anemia. What is an optimal supplementation? Iron deficiency is common in the elderly. Many studies have shown that zinc is essential to maintain function of the immune system. The daily need for zinc is about 25 mg, of which 11 mg is provided by diet, and so 14–15 mg/day of zinc may be an optimal dose. Many trials have studied vitamin E, a potent antioxidant. The optimal dose for vitamin E seems to be in the range of 200 IU. Also, 100 μg selenium, when given with zinc, reduces infections independent of vitamin supplementation. As pointed out earlier, large doses of any one nutrient may be harmful, and singling out any one nutrient may not be physiological, as with time, deficiency of the other nutrients may develop. Thus, an adequate approach would be a multivitamin and trace mineral supplement containing zinc (14–20 mg), selenium (100 μg), and vitamin E (200 mg). That stated, it should be further emphasized that optimal nutrition

remains incompletely understood, and contradictory studies for each of the mentioned nutritional supplements have been reported.

Vaccines

Various vaccines have well-established roles in prevention of infectious diseases at all ages. Pneumococcal, influenza, and tetanus vaccines are effective in preventing disease and decreasing mortality in the elderly. With age, the time to development of protective antibody titers after vaccination is delayed, peak antibody titers are lower, and there is a faster decline of the protective titers. Yet healthy elderly (without extensive comorbidity) may reach titers, although lower than observed in younger recipients, that are protective. Furthermore, even without reaching protective titers, when the target infection occurs, the clinical severity is likely to be less.

Exercise

The capacity for exercise to reconstitute age-reduced immunity remains controversial. Acute bouts of strenuous exercise are deleterious to immune function, but moderate aerobic activity has been correlated with better functioning, at least as measured by *in vitro* assays. Elderly who regularly exercise and are overall well conditioned have demonstrably better immune function. On the other hand, exercise programs undertaken after the onset of immune dysfunction do little to enhance immunity. Because many of the studies evaluating effects of exercise were cross-sectional, it remains to be determined if the better immune function observed in well-conditioned elderly is due to the effects of exercise or is a result of overall healthy lifestyle choices.

Novel Approaches

Various novel approaches to enhance immunity have also been tried, including hormonal replacement including thymic hormones, intravenous immunoglobulin, and caloric restriction. At present the data do not support the non-investigational use of any of these approaches.

Caloric restriction without malnutrition has produced promising results in murine models, showing prolonged survival and immune competence into late life. Similar studies in non-human primates are also ongoing and have shown encouraging results. The National Institute on Aging has recently initiated similar nutritional intervention studies in humans.

Summary

Diminished immunity in the elderly is complex and multifactorial. There is no question that aging itself diminishes endogenous immune function, but the clinical consequence of this degree of impairment is likely to be slight. Reactivation of latent infections, such as herpes zoster or tuberculosis, may be caused by this impairment, and certainly a diminished response to influenza and pneumococcal vaccines has been demonstrated in otherwise fit elderly. The typical geriatric patient, however, may have a more profound immune deficiency because of the coexistence of diseases, malnutrition, and the use of powerful medications. Such patients are clearly more susceptible to infection and possibly other diseases, including certain malignancies, on the basis of this composite immune deficiency. Efforts to reconstitute age-associated immune deficiency have had limited success; further research of the traditional approaches using rigorous clinical trial methodology as well as the development and investigation of novel approaches are warranted.

See also: Diet and Nutrition; Exercise and Physical Activity; Long Term Care.

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Information Processing/Cognition

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Glossary

Attention – The limited resources or mental energy required for task performance, the selection of relevant information from the environment, the simultaneous division of focus between tasks or stimuli, or the monitoring of the environment for a particular event over an extended period of time.

Reaction Time (RT) – The minimum amount of time, measured from the onset of the stimulus to the execution of a response, needed to make a correct response.

Speed-Accuracy Operating Characteristic – Accuracy decreases as a function of increasing speed.

Introduction

Modern cognitive psychology and the information processing approach came into prominence during the 1960s due, in part, to the limitations imposed by behaviorism, the dominant paradigm in psychology at that time. By restricting explanatory constructs entirely to observable behavior, behaviorism led researchers to neglect mental processes used in memory, attention, and problem solving. At the same time that the information processing approach was flourishing, there was also a great deal of research being conducted examining the biological and cognitive changes in older adults. Thus, the information processing approach has long been used in the psychology of aging to investigate the cognitive abilities of older adults.

The first goal of this article is to provide a description of the information processing approach along with some of the methods used to investigate the various components of cognition. It then describes the use of these methods to investigate normal, age-related changes in a variety of cognitive domains along with a description of compensatory mechanisms used to offset some of these declines. The article concludes with a discussion of the cognitive neuroscience of aging, a relatively new field of science concerned with investigating age-related changes in the brain and how they relate to age deficits in cognitive performance.

Understanding Components of Complex Processes

In the information processing approach, reaction time (RT) is an important variable of interest. Reaction time is traditionally defined as the minimum amount of time, measured from the onset of the stimulus to the execution of a response, needed to make a correct response. Thus, we can observe variations in measurable aspects of behavior, especially RT, and from these variations make some inferences regarding the nature of the underlying mental events – the information processing architecture – leading to responses in perceptual and cognitive tasks.

Subtraction Method

In 1868, the Dutch psychologist Donders proposed the subtraction method as a procedure for estimating the amount of time occurring during mental events. The method involves subtracting the RTs between tasks structured to differ in specific ways. For example, consider three different RT tasks, Task 1, Task 2, and Task 3, illustrated in **Figure 1**. Task 1, a simple RT task, involves the presentation of a single stimulus and a single response, for instance, pressing a key whenever a light is presented. Task 2, go/no-go, involves presenting two stimuli along with a single response. In this task, a light could occur in either the left or the right position; however, a response would be made only if the light appeared in the right position. Participants would refrain from making a

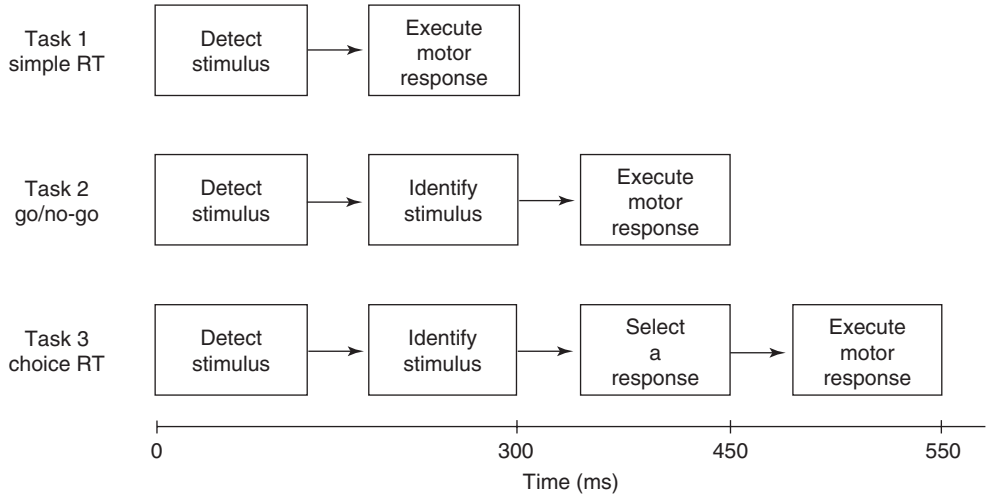

Figure 1 Donder's subtraction method. Tasks are constructed to isolate various processing stages. Task 2, for instance, takes longer than Task 1 due to the insertion of an additional processing stage representing the identification of the stimulus. To obtain the time required to identify the stimulus, the mean RT for Task 1 is subtracted from the mean RT for Task 2.

response when the light appeared in the left position. Finally, Task 3, choice RT, involves the presentation of two stimuli along with two responses, for instance, pressing one key when a light is presented on the right side of the computer screen and another key when the light is presented on the left side. This method is based on the assumption that Task 2 contains all the stages of Task 1 with an additional inserted stage representing the time required for stimulus identification. Further, this method assumes that Task 3 has all the same stages as Task 2, with an inserted stage representing the time needed to select a response. As shown in **Figure 1**, to estimate the amount of time needed to identify a stimulus, the mean RT from Task 1 is subtracted from Task 2. Similarly, subtracting Task 2 from Task 3 provides an estimate of the amount of time needed to select a response.

Note, however, that this method assumes that the only difference between each of these tasks is the addition of a single processing stage, either stimulus discrimination or response selection. A complication is that the insertion of an additional stage may in some instances also influence other stages of processing. Further, this method requires an *a priori* theory regarding the information processing stages required by a particular task.

Additive Factor Method

In contrast to the subtraction method, the goal of the additive factor method is to provide evidence for the existence of discrete processing stages rather than simply determining the amount of time required for processing at a particular stage. The additive factor method relies on the interpretation of the results in performance associated with particular variables (or factors) that can be varied systematically. These factors are features of the task, such as the degree of noise in the stimulus or number of responses, which can take on a number of empirical values. If factors have only additive effects on RT (i.e., statistical main effects), it is concluded that each of these factors is independent and affects separate processing stages. For example, if the increase in RT associated with increasing noise in the display, relative to a clear display, was the same regardless of the number of responses that were required, then it would be concluded that in this task the perceptual noise and response selection factors are additive and that the encoding and response stages are separate. In contrast, the finding of significant statistical interactions between pairs of factors (e.g., a greater effect of noise on RT when the number of required responses increased) represents a situation where the two factors are not separate and additive but instead interact, having some influence in a common processing stage.

This method was first used by Sternberg to investigate processes involved in short-term memory. In this experiment, participants viewed a memory set of sequentially presented digits and then after a brief delay saw a probe letter. Participants made a positive response if the probe was part of the previously presented memory set, otherwise they made a negative response. Sternberg studied the effects of several factors, including the visual quality of the digits (clear or degraded), memory set size (1–6 digits), response type (positive or negative), and response type frequency (e.g., percentage of trials in which a positive response was required). These various manipulations

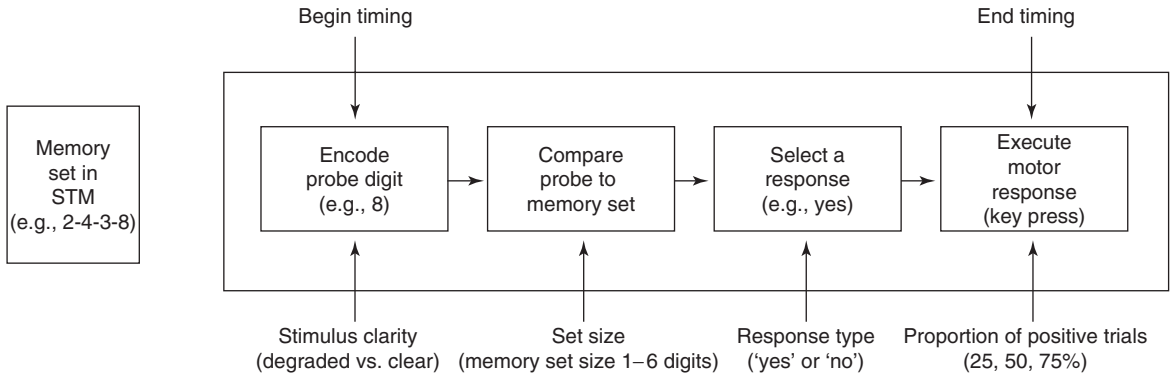

Figure 2 Additive factors methodology showing the factors proposed to affect various processing stages. Timing begins at the onset of the probe digit, after the memory set has been encoded, and ends when the appropriate key is pressed to indicate a response.

had additive effects on RT, suggesting that this task involved four processing stages, illustrated in **Figure 2**: an encoding stage; a comparison stage, in which the internal representation of the memory set is compared to the probe digit; a response selection stage; and a response execution stage, in which the observer executes a motor response by pressing the appropriate key.

From an information processing perspective, chronological age can be considered another factor, and the pattern of additivity and interaction, among age and other experimental variables, can be used to identify the locus of age-related change within a particular task. In the case of short-term memory, for example, interactions with age have been observed with virtually all of the stages. Age-related slowing is thus not restricted to peripheral processes of encoding and responding but is also associated specifically with the search through the items in short-term memory.

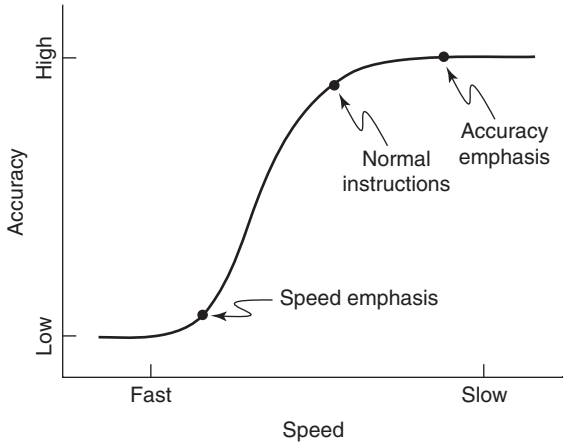

Figure 3 A speed–accuracy operating characteristic. Points on the curve represent the hypothetical results that would be achieved in an experiment placing varying degrees of emphasis on speed versus accuracy.

Speed–Accuracy Tradeoffs

As mentioned previously, RT is defined as the minimum amount of time that participants need to make a correct response. In practice, however, that minimum point is difficult to define. For any particular response, how can we be sure that the participant could not have responded more quickly and still have been correct? Thus, it is usually necessary to elicit a small proportion of incorrect responses, to provide some indication that participants are attempting to respond quickly. On the other hand, the majority of responses must be correct, to ensure that there is reliability in the RT data and that the participant is not simply guessing. Information processing tasks thus usually assume a particular relation between speed and accuracy. A typical pattern of results is that accuracy decreases as a function of increasing speed. This pattern can be observed empirically by requiring participants to place a varying degree of emphasis on speed versus accuracy. The speed–accuracy operating characteristic in **Figure 3** represents these results, with fast, inaccurate responses represented to the left and slow, accurate responses represented at the right.

One difficulty in interpreting age-related changes in RT is that different groups of participants may vary in their emphasis on speed versus accuracy, that is, in the relative proportion of errors they will accept in attempting to respond as quickly as possible. Thus, differences in RT between younger and older adults may not be due entirely to differences in processing speed but also to differences in setting a response criterion on the speed–accuracy function.

Distributional Analyses

The approaches just described typically use some index of central tendency (e.g., mean or median) to

summarize performance across many trials in each task condition. Typically, however, the RT data are not distributed normally but rather are skewed positively (i.e., extreme responses are more likely to be slow than fast). Thus, using a summary index ignores potentially important information in the data. By using the entire distribution of RTs, researchers found that age differences increased in magnitude for the slower responses in the distribution, a pattern thought to reflect age-related difficulties in concentrating or ignoring task-irrelevant information.

These types of distributional analyses are related to a more general emphasis on developing a formal model of the information processing components required by a particular task. Rather than focusing on the effects of individual variables, as in the subtraction and additive factor methods, formal modeling approaches emphasize the estimation of model-based parameters representing specific information processing components. Researchers can then test whether there is an adequate fit between the observed data (both RT and accuracy) and the values predicted from the model. If this fit is adequate, then the specific parameters are interpretable. For instance, a model may include different parameters for decisional processes, non-decisional processes (e.g., perceptual motor processes), and the amount of information and time required to reach a decision. Using this approach, several researchers have found that, compared to younger adults, older adults exhibit larger non-decisional components and require the accumulation of more stimulus information before initiating a response.

Generalized Slowing Explanations of Age-Related Decline

As noted previously, age-related slowing occurs in many aspects of information processing. An early study by Brinley raised an enduring question, regarding the degree to which age-related slowing is general or task-specific. It slowing is a general property of the aging central nervous system, then the types of task-specific analyses provided by information processing techniques may not be necessary. To investigate this issue, Brinley tested younger and older adults on a variety of tasks tapping verbal ability, arithmetic skills, and perceptual processing. In each if these categories, some tasks required shifting attention across trials while other tasks did not. When the mean RTs of the older adults, in each of the task conditions, were plotted as a function of the corresponding mean RTs of younger adults, Brinley found that the performance of older adults could be expressed as a highly linear function of the younger adults' RT ($r = 0.99$). In this type of analysis, currently known as a Brinley plot, slopes greater than 1.0 provide evidence that age-related decrements reflect declines in speed of processing, relative to younger adults. In other words, due to the aging process, older adults may exhibit a generalized decrement in speed of processing, rather than one associated specifically with certain information processing stages. Numerous studies using Brinley's technique provide support for these types of generalized slowing models. It should, however, be noted that not all researchers agree with the generalized slowing interpretation of the Brinley plot analysis and instead argue that the obtained slowing function represents the relative standard deviations in RT for older versus younger adults (**Figure 4**).

Building on this earlier work investigating slowing in older adults, Salthouse presented his processing speed theory, which proposed two mechanisms to explain the relationship between age-related changes in speed and age-related changes in cognition, a limited time mechanism and a simultaneity mechanism. The limited time mechanism represents the fact that older adults are not able to complete the processing of earlier operations in the available time, whereas the simultaneity mechanism represents the fact that due to slowing, the products of earlier operations are lost and become unavailable for use during later processing stages. An approach used by Salthouse and others is to assess the speed of processing independently, by having participants complete elementary perceptual-motor tasks such as simple RT, choice RT, or digit-copying tasks. Then, when assessing age

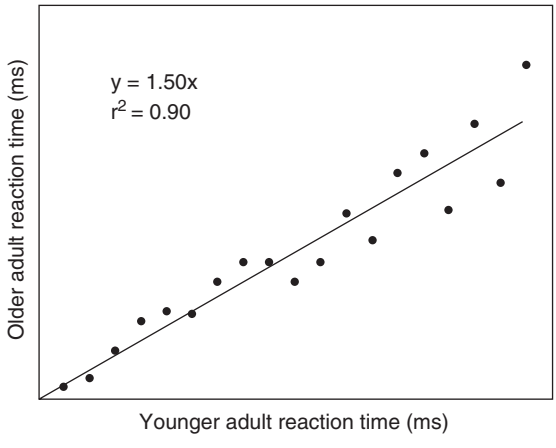

Figure 4 A Brinley plot showing the mean RTs for older adults plotted as a function of the mean RTs for younger adults. Reprinted from Madden DJ and Whiting WL (2004) Age-related changes in visual attention. In: Costa PT and Siegler IC (eds.) *Advances in Cell Aging and Gerontology,* p. 48, Copyright (2004) with permission from Elsevier.

differences in some outcome measure of cognitive performance, the mediating influence of elementary processing speed can be determined from hierarchical regression procedures. Using this approach with a variety of cognitive tasks as outcome measures, researches have found that the age-related variance in task performance was substantially reduced, or eliminated entirely, after controlling for processing speed, thus providing further support for generalized slowing.

Generalized slowing explanations are appealing because they provide a parsimonious explanation for the differences between younger and older adults. However, other explanations may account for these cognitive declines including reduced processing resources, inhibitory deficits, attentional control deficits, and reduced working memory capacity. Thus process-specific influences, as well as generalized slowing, are needed to explain age-related deficits in cognitive performance. The following sections on memory, attention, and problem solving will highlight several areas of cognition including task-specific versus generalized slowing explanations for age-related declines.

Memory

Difficulty remembering information is usually one of the first cognitive changes that people notice as they grow older. For instance, older adults may notice that they are misplacing their keys more frequently or are relying more often on calendars to remember appointments. Indeed, as noted previously, laboratory investigations of memory have found age-related declines on several processing stages within memory tasks. Not all aspects of memory, however, are affected equally by the aging process. To make sense of this diverging pattern of results, it is useful to understand some of the various structures that comprise the memory system.

Typically, long-term memory is subdivided into declarative or explicit memory and procedural or implicit memory. This distinction is based on whether information is intentionally retrieved (explicit) or whether information indirectly influences some other behavior, without the conscious retrieval of that information (implicit). Declarative memory is further subdivided into episodic memory (memory for specific episodes or contexts) and semantic memory (memory for general, context-independent knowledge). A typical finding is that smaller or non-existent age differences occur in tasks thought to measure implicit compared to explicit memory. However, within the explicit component of memory, dissociations are also found between semantic and episodic memory.

Explicit versus Implicit Memory

Explicit memory is traditionally measured using tests of recall and recognition, in which participants consciously refer back to the original learning or encoding of the material to complete the test. In contrast, implicit memory tests indirectly assess memory by having participants complete tests that are supposedly unrelated to the encoding condition. For example, in word stem completion, a commonly used implicit memory test, participants are provided with the first few letters of a word followed by a blank space (e.g., m a i). Participants are more likely to use the word 'maiden' to complete the stem if they had previously encoded that word rather than the more commonly occurring word 'mail.' Implicit tests such as word stem completion are useful in investigating learning that occurs indirectly, without conscious awareness. Researchers have often found that age-related decline is minimal for these types of implicit memory tests. Although under some conditions age-related decline for implicit memory does occur, it is generally the case that implicit memory is relatively spared in older adults.

Episodic Memory

Most research provides evidence that pronounced age deficits are observed for episodic memory – memory for specific, context-dependent information. An everyday example is remembering whether or not one has taken their medication that morning. In the laboratory, episodic memory is tested using recall and recognition tests. In these tests, which typically use accuracy as the variable of interest, participants are presented with lists of stimuli (e.g., pictures, words) and are instructed to try to remember the information over a period of time. In tests of recall, participants are then required to reproduce or recall the information, whereas on tests of recognition, participants are presented with stimuli, some of which were presented during the original encoding, and are then asked to determine whether the material was presented previously. A typical finding is that for tests of recall accuracy, large age deficits are found, whereas for tests of recognition accuracy, the age deficits are usually smaller or non-existent.

This pattern is believed to reflect the differential reliance by older adults on environmental support. Converging evidence for this idea has been obtained using the RT distribution approach described earlier. The effects of age in RT on a recognition memory test were completely eliminated after controlling for the fastest responses of the distribution, a finding consistent with a generalized slowing account of aging. For recall RT, however, age continued to be a

significant predictor of performance, a finding that supports the environmental support theory. Further, age differences are even more pronounced when older adults have to remember the specific source or context of the information, for instance, whether a news story was read in the newspaper or heard on the radio. Thus, an increased reliance on environmental support would be useful in offsetting a deficit in identifying the original context of memory information. As mentioned earlier, older adults also tend to be more distracted by irrelevant information, and environmental support would aid the ability to focus on task-relevant information.

Semantic Memory

Researchers have conceptualized semantic memory as being organized as a linguistic or conceptual map, consisting of a network of nodes or concepts linked together by a series of pathways. The degree of relatedness among concepts is expressed in terms of the length of the pathways. Thus, related concepts such as robin, bird, and fly would have relatively short pathways between them, whereas the pathway from robin to bulldozer would be relatively longer. Once a concept is activated (e.g., bird), activation tends to spread to other nearby nodes (e.g., wing, feather), thus activating them in the process. Further, it has been proposed that concepts that are activated frequently become strengthened and become easier to retrieve compared to concepts that are activated less frequently.

Age differences in semantic memory tasks such as vocabulary, general knowledge, and word identification tend to be small in magnitude, after controlling for slowing at the perceptual motor level. Researchers also use lexical decision tasks to investigate how information is stored and activated in semantic memory. In these tasks, participants are presented with a string of letters and are required to make a decision as to whether the letter string forms a word (e.g., bank) or a pronounceable non-word (e.g., tolph). A typical finding is that people are faster to respond to higher-frequency compared to lower-frequency words (i.e., the word frequency effect). Similarly, when memory information related to the target word is activated in advance (i.e., primed) by the presentation of a semantically related word, responses are faster than when the target word is not primed. These effects of word frequency and priming tend to be at least as great for older adults as for younger adults, implying a preservation of semantic memory functioning.

Although many components of semantic memory are relatively preserved with increased age, one common memory problem for older adults involves the retrieval of familiar information from semantic memory, for instance, the names of objects and individuals. One example of this is the tip-of-the-tongue (TOT) state, in which the individual is unable to retrieve familiar information but has the feeling that the information is available (i.e., is still located in semantic memory). Although both older and younger adults experience TOT states, laboratory investigations have found that older adults experience significantly more TOT states than younger adults. One explanation for increases in TOT states in older adults is the transmission deficit hypothesis. According to this hypothesis, connections between nodes become weak with increased age, resulting in impaired transmissions between nodes. The reason for age-related increase in TOT states is not entirely clear, but it may be related to the additional redundancy among pathways available for semantic information, relative to the pathways for linguistic sounds (i.e., phonology) that are needed to retrieve specific words.

Attention

Attention can be viewed in several ways: as the limited resources or mental energy required for task performance, the selection of relevant information from the environment (selective attention), the simultaneous division of attention between tasks or stimuli (divided attention), or the monitoring of the environment for a particular event over an extended period of time (vigilance). Many laboratory tasks as well as everyday tasks (e.g., driving) may comprise a combination of various forms of attention. Although older adults experience deficits in many attentional components, there is some preservation of attentional functioning with age as well. This discussion is restricted to the visual modality, which has comprised the majority of the published research reports, but related findings have also been observed in the auditory modality.

Processing Resources

One conceptualization of attention is that it is a limited supply of processing resources required for the performance of other cognitive tasks. In dual-task situations, for example, as the primary task becomes more demanding (e.g., driving under adverse conditions), additional attentional resources can be allocated to the primary task by reducing those being used by a secondary task (e.g., lowering the volume on the radio). Based on the results of laboratory dual-task experiments, researchers have proposed that age-related deficits on cognitive tasks are due to

reductions in processing resources (i.e., the resource deficit hypothesis). Performance in the dual-task condition is usually worse than when either task is performed separately, with greater decrements exhibited by older adults. To assess the cost of performing the two tasks separately, an attention operating characteristic (AOC) is constructed, with data from Task 1 plotted along the *x*-axis and data from Task 2 plotted along the *y*-axis. Task priority can be manipulated by including conditions in which participants prioritize Task 1, Task 2, or both tasks. The area above the AOC represents the cost of performing the two tasks simultaneously. A typical finding using the dual-task procedure is that older adults show a greater divided attention cost than younger adults.

The resource deficit approach has often been criticized due to the lack of an explicit definition of resources and how they are to be measured. Thus, researchers have specified particular components that could be considered resources, including speed of processing, working memory capacity, and inhibition. One of these proposed processing resources, working memory, has been conceptualized as the component of memory responsible for the simultaneous storage and processing of information. Researchers have proposed a model of working memory consisting of two components that maintain verbal/phonological and visual information in memory over time. This model of working memory also proposes an executive control system that coordinates and controls the flow of incoming information to these two systems. This proposal has been tested with tasks measuring verbal reasoning and spatial abilities using the hierarchical regression technique described previously. As predicted, the statistical control of working memory resources (as assessed by an arithmetic span task) attenuated the effects of age on both of the cognitive tasks.

Selective Attention

In visual search tasks, participants are required to identify a target item from among one or more distractor (i.e., irrelevant) items, with the total number of items in the display (i.e., display size) varying across trials. As display size increases, search becomes more difficult or less efficient. By varying display size it is possible to determine the relative efficiency of the search and whether specific types of attentional manipulations (e.g., providing a spatial cue) facilitate search. To illustrate, searching for a specific book among six books is much easier than searching for the same book among an entire shelf of books. The less efficient search among an entire shelf of books can be made more efficient by top-down (i.e., goal-directed) knowledge that the target book is located on the right side of the shelf. Further, a red book among a shelf of tan books will capture attention in a bottom-up or stimulus-driven fashion and will facilitate search if the red book also happens to be the book that one is looking for. Reaction time is analyzed as a function of display size. Efficient searches tends to have linear RT $\times$ display size slopes that are less than 10 ms per item; search slopes of 20–30 ms per item or greater indicate less efficient search.

Researchers interested in possible age differences in visual search performance have compared performance in feature search tasks, in which a target item is defined by a single feature (e.g., searching for a T among Os), to performance in tasks in which the target is defined by a conjunction of two features, for instance, searching for a T from among Ls and Fs. The general finding from this research is that larger age differences are found in conjunction tasks compared to feature search tasks in which target items tend to pop out from among the distractors in the display. Different forms of improving search efficiency, however, such as using consistent target and distractor colors within a block of trials, or cuing the spatial location of the target, tend to be at least as effective for older adults as for younger adults.

In addition to selecting relevant information, selective attention also involves the ability to inhibit irrelevant or distracting information. The Stroop task is often used to measure the degree of interference produced when participants are presented with irrelevant information. In a typical computerized version of this task, participants are presented with words printed in colored ink and are simply instructed to name the color of the ink in which the word is printed. Sometimes the identity of the word is congruent with the ink color (the word 'red' printed in red ink) and sometimes it is incongruent (the word 'red' printed in green ink). Thus, on incongruent trials, the relatively automatic process of reading must be inhibited in order to comply with the instructions of the task. For both older and younger adults, RT tends to be higher in the incongruent condition, with older adults showing greater susceptibility to Stroop interference than younger adults. This age difference remained even after using procedures to control for generalized slowing. In a variant of this task, researchers presented the color name in a neutral color that was spatially separated from a block of color (congruent or incongruent with the word). In this situation, older adults are similar to younger adults in being able to use the spatial information to successfully inhibit the irrelevant information, thus reducing Stroop interference.

Divided Attention

Age-related decline in cognitive tasks tends to be most pronounced when some division of attention is required. Attention can be assessed by having participants perform two tasks concurrently (the dual-task procedure), as mentioned previously, or by having them switch unpredictably between two different types of tasks (i.e., task switching). In a task-switching procedure, participants perform two different choice RT tasks in separate blocks containing only a single type of task and in blocks in which both tasks are randomly intermixed. For instance, one task may require participants to decide whether a digit is odd or even, while the other task may require participants to judge whether stimuli are smaller or larger than a computer monitor. Successful performance of this task requires various attentional control processes such as inhibiting the previously relevant task along with the activation of the current task. The results from this research show that older adults exhibit greater task-switching costs when switching between different single-task blocks (global task switching) compared to switching between tasks within a mixed block of trials (local task switching). Further, the costs associated with global task switching appear to be greater than those predicted by a model of generalized slowing, whereas the costs associated with local task switching are more consistent with a model of generalized slowing. Thus, consistent with some of the research investigating working memory performance, this research shows that older adults tend to show the most pronounced age-related decline on tasks that require a great deal of attentional control.

Sustained Attention

In sustained attention or vigilance tasks, participants are required to monitor the environment over an extended period of time while searching for a predefined target. One commonly used vigilance task is the Mackworth clock test. In this task, participants are required to monitor the movements of a pointer on a clocklike device over the course of an hour. The pointer typically moves one step at a time with relatively infrequently occurrences when the pointer moves two steps. The goal of the task is to detect all the two-step movements of the pointer. On tests of simple vigilance older adults typically do not show decrements in performance compared with younger adults. However, when complex vigilance tasks are used, for instance, detecting a small red square among larger red squares, age-related declines are observed, especially if the stimuli are visually degraded or presented at a rapid rate. Further, these age differences remain even with extensive practice on the task.

Problem Solving

Researchers interested in problem solving have been especially interested in how problem-solving abilities change as people age, because these abilities have typically been defined as fluid abilities and thus tend to show sharp declines with age. The processes required for the solution of any problem consist of three sequential stages: preparation, production, and judgment. During preparation, the initial state of the problem is identified and an internal representation of the problem is formed. Next, during the production stage, relevant information is retrieved from long-term memory to assist in the generation of an appropriate problem-solving strategy. Finally, during the judgment stage, the proposed solution is evaluated to determine whether the problem has been correctly solved. Age differences are typically observed in the first two sequences of problem solving because of age-related declines in working memory capacity and greater difficulty inhibiting irrelevant information. However, some research suggests that older adults tend to be more cautious, which would affect the judgment stage. Many investigations of problem solving rely on accuracy rather than RT measures and use the verbal reports of participants to reveal their problem-solving strategies.

The Tower of Hanoi task is one example of an information-processing task that measures how people solve problems. In this task, participants are presented with three pegs. The first peg contains three different-sized disks, A, B, and C. The largest disk (C) is on the bottom, the next largest disk (B) is in the middle, and the smallest disk (A) is on top. The other two pegs are empty. The goal is to move the three disks from the first peg to the third peg so that C is on the bottom, B is in the middle and A is on top, with the constraint that only one disk can be moved at a time and that a larger disk can never be placed on a smaller disk. Research comparing the performance of younger and older adults has found that initially older adults use more moves to obtain the correct solution and take longer to perform each move compared to younger adults. Both age groups, however, are able to improve their performance over several blocks of trials, indicating that this type of fluid ability can be improved through practice.

A current trend in cognitive psychology involves the investigation of everyday problem-solving abilities and how they may change as a function of increased age. Because everyday problems may be less abstract and more relevant to older adults,

researchers speculated that this type of problem solving would not show pronounced declines with age. In these tasks, participants are asked to solve a series of everyday problems (e.g., what would you do if you turned on your oven and after 10 minutes noticed that it was not getting warm?). Raters then judged the responses according to the overall quality of the response as well as the likelihood that the response would solve the problem. Even when the scenario involved realistic events, older adults still performed more poorly than either younger or middle-aged adults. Although older adults tend to perform more poorly than younger or middle-aged adults on a variety of problem-solving tasks, there is evidence that older adults can improve their problem-solving capabilities through the use of specific skill training and interventions.

Compensatory Mechanisms

It is possible for older adults to compensate for some age-related cognitive declines through practice and experience. In other words, the development of crystallized abilities through experience can offset some of the biologically based declines that are normally experienced on tests requiring fluid abilities. To investigate how older adults use compensation and expertise to offset losses, one researcher investigated how skilled older adult typists are able to maintain high levels of performance on the task of typing. In this sample of older and younger adults there was no correlation overall between age and typing performance. Participants completed a variety of tasks, including simple RT tasks and typing tasks, which varied the amount of text available to view while typing. The compensatory mechanism revealed in this study was that older adults had a larger eye–hand span, the minimum amount of preview needed to approximate normal typing speeds, than the younger adults. In other words, to compensate for declines in speed of processing, older adults were able to look ahead a few more extra text characters than the younger adults.

Cognitive Neuroscience of Aging

Cognitive neuropsychology involves investigating how various cognitive processes are linked to various structures in the brain. Although researchers have long been interested in these issues, the development of structural and functional neuroimaging techniques within the last 20 years has led to a rapid increase in our understanding of the brain–cognition relationship and how this changes as a function of increased age. Two widely used methods are positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). In PET, changes in regional cerebral blood flow (rCBF) are measured from the tissue clearance of a radionuclide tracer, either at rest or during the performance of a cognitive task. The more recently developed technique, fMRI, measures changes in the blood oxygen level dependent (BOLD) signal. The BOLD signal (which is correlated with cerebral blood flow), is obtained from an MRI scan, using magnetic field and radio frequency pulses, and thus avoids the administration of a radionuclide tracer. Both PET and fMRI measure the changes occurring in gray matter (i.e., cortical regions) during task performance. These cortical regions, however, are interconnected by white matter tracts that may also undergo changes as a function of age, thus impairing the transmission of information between brain regions. Researchers interested in changes in white matter integrity use a recently developed technique called diffusion tensor imaging (DTI). This method measures the displacement of water molecules across tissue and thus allows researchers to investigate changes in white matter integrity as a function of age.

Using fMRI, researchers have proposed that a frontoparietal brain network is involved in the performance of attentional tasks that require the use of top-down attentional control processes. Deep gray matter structures such as the thalamus and basal ganglia are also thought to play a role in attentional processing through connections with the frontoparietal network. These investigations suggest that age-related decline occurs in the activation of the occipital cortex. In addition to decreased activation in visual areas, increased activation is often observed in the frontoparietal attentional network, especially the dorsolateral prefrontal cortex. Further, increased activation of deep gray matter along with parietal cortex have also been observed for older adults. A similar pattern of results has also been found using PET in a comparison between selective and divided attention performance in younger and older adults. Larger age differences were found in RT and accuracy on the divided attention task, compared to the selective attention task, as well as in rCBF. For younger adults in the divided attention task, greater activation was obtained in the occipital cortex, whereas for older adults, greater activation was obtained in the prefrontal cortex (PFC). Based on these results, researchers have proposed that older adults compensate for declines in areas of basic visual processing (occipital cortex) by recruiting additional areas in the frontoparietal network.

Imaging procedures are also used to investigate the brain regions activated during memory tasks. For

instance, researchers interested in brain regions involved during episodic memory have found that for younger adults, brain activity tends to be greater in the left PFC during encoding, whereas during retrieval, the right PFC shows greater activation. For older adults, however, bilateral activation has been observed during both encoding and retrieval. This reduction in asymmetry may be another form of compensatory mechanism. Studies have supported this hypothesis by demonstrating that increased bilateral activation is associated with better performance on the cognitive task.

Investigations of white matter tracts have also yielded important information regarding the relationship between declines in cognitive tasks and deterioration in white matter tracts that impair the transmission of neural information between cortical regions. Using DTI, researchers have found greater declines in the integrity of the white matter in anterior regions compared to more posterior regions. Interestingly, these declines in white matter integrity were associated with decreased performance on cognitive tests requiring a high level of attentional control.

Conclusions

Older adults experience age-related declines in many areas of cognition, but these declines are not universal; they instead represent a complex pattern of stability and loss. Although losses have often been explained in terms of a generalized slowing account, it is clear from the research that process-specific as well as generalized slowing models are needed to account for these age differences. Recent advances in neuroscience will allow researchers to combine the information-processing approach with imaging techniques such as fMRI and DTI, leading to a better understanding of the brain–cognition relationship and how this changes as people grow older.

Acknowledgments

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See also: Attention; Decision Making and Everyday Problem Solving; Memory; Neuroimaging (MRI, PET); Reaction Time.

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Inhibition

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Glossary

Distraction – The state of having been diverted from a previous focus of attention, usually by some other, irrelevant stimuli.

Facilitation – The cognitive process by which relevant information is given priority in the limited-capacity information-processing system.

Inhibition – The cognitive process by which irrelevant information is prevented from gaining access to the limited capacity information-processing system.

Selective Attention – The interaction of facilitative and inhibitory processes that control the focus of information processing, allowing the individual to concentrate on relevant information and ignore irrelevant information.

Visual Search Paradigms – Any of a variety of tasks that require the individual to locate a target item in a display containing both relevant and irrelevant items.

Introduction

Because the momentary capacity of the human information-processing system is limited, access to the system must be controlled so that relevant information is processed and irrelevant information is not. Selective attention is typically the mechanism that controls access to the processing system. This mechanism is hypothesized to involve both the facilitation of relevant information and the inhibition or suppression of irrelevant information (e.g., irrelevant sensory stimuli). Breakdowns in inhibitory function result in distraction and an associated decline in information-processing efficiency. Thus, in the domain of cognitive function, inhibitory processes are thought to facilitate the selective processing of information to maximize the behavioral efficiency of the individual.

Inhibition in Information Processing

In the context of adult development and aging, the notion that altered inhibitory function might underlie many age-related cognitive changes has been considered since the 1950s. Birren (1959: 37) stated the notion of inhibitory decline "has heuristic value for many reported age differences." Pavlov hypothesized that age-related declines in inhibitory function produced the difficulties he observed on the part of older adults in discrimination learning tasks, in extinguishing previously learned responses, and in the control of language functions. In the intervening decades, a number of lines of work have been initiated to further examine the role of inhibitory function in age differences in cognitive abilities. Although initially postulated as a general age-related deficit potentially underlying many of the cognitive changes associated with age, the conclusion from a considerable body of work is that age-related inhibitory deficits are observed in some tasks but not in others, thus circumscribing its explanatory utility.

Physiological Indices of Inhibition

The Orienting Response

Studies of the autonomic orienting response (OR), a complex pattern of physiological changes elicited by novel and/or significant stimuli, provide one approach to understanding the role of inhibition in information processing. These studies assume that the OR indexes the engagement of attention and that the magnitude of the OR indexes the extent to which attention is engaged. A further assumption is that inhibitory processing modulates the OR in line with current task demands and behavioral goals. That is, when information is no longer significant or novel, the OR is suppressed. An age-related inhibitory deficit would thus manifest itself as a pattern of ORs that continue to be elicited even after novelty or significance has worn off, or that are elicited in response to stimuli that are not relevant to the current circumstances.

Studies using the OR to index attention and the suppression of attention in young and old adults have provided some evidence for an age-related decline in the efficiency inhibitory function. For example, in a task requiring individuals to attend to some stimuli and ignore others, young adults showed evidence of differential orienting, but older adults did not. That is, to-be-ignored stimuli elicited the same physiological response in older adults as the task-relevant information, indicating a failure of inhibitory processes to modulate and suppress a response to the irrelevant information. This pattern of results suggests that older adults are less efficient in the

control of attention and so may be less efficient information processors (*see* Attention).

Brain Activity and Functional Imaging

Inhibitory processes in cognition are typically associated with the frontal lobes of the brain, more specifically, the dorsolateral prefrontal cortex (DLPFC). Two types of approaches have been applied to understanding the brain activity associated with inhibitory processes in aging. In the first approach, inhibitory task performance of older adults is compared to that observed in people with DLPFC damage. Findings from this approach indicate significant similarity between the two groups, suggesting that the function of the DLPFC is impaired even in normal aging and that it may be responsible for age-related inhibitory deficits.

The second approach involves functional imaging of brain activity during inhibitory task performance. Using fMRI technology, the brain areas active during inhibitory tasks can be identified, and age groups can be compared in terms of this activation. Although few studies have been published in this area, there is evidence indicating that both young and older adults show activation of the prefrontal cortex when engaged in a go/no-go task requiring inhibition of responses. However, older adults appear to show more extensive activation, in areas not activated by young adults. This pattern of findings may reflect compensation for altered inhibitory function among older adults, and appears to be a promising area for future research.

Behavioral Indices of Inhibition

Visual Search

Selective attention is the mechanism that facilitates the processing of relevant information and suppresses irrelevant information. Failures of selection result in the capture of attention by irrelevant information, commonly called distraction. Many studies in the literature have indicated that older adults are more susceptible to distraction than young adults, and these studies have been used as evidence to bolster the hypothesis that older adults are less able to inhibit irrelevant information than young adults.

In Patrick Rabbitt's classic work on age and distraction, young and older adults sorted cards on the basis of prespecified letters printed on the card. Rabbitt observed that the presence of irrelevant letters arranged randomly around the card slowed the sorting times of older adults more than it did for young adults. He concluded that the older adults were less able to avoid distraction than young adults. By implication, therefore, altered inhibitory processes have been deemed responsible for producing this pattern of results.

Rabbitt's work was followed by other studies designed to explore the parameters that determined the presence and extent of any age-related increase in distractibility. Visual search tasks have frequently been used to assess the efficiency with which individuals can locate and/or identify a target in the presence of distracting, non-target information. One of the generalizations that has emerged from this work is that when selection and suppression can be guided by physical cues such as color, shape, or location, older adults perform comparably to young adults. However, when there is uncertainty about what or where to attend to, older adults are typically at a significant disadvantage relative to young adults.

A similar pattern of results has been observed with the Stroop task. This task requires individuals to name the color in which a color word is printed. For example, if the word 'red' printed in green ink is presented, the task is to name the color 'green' and inhibit responding to the word 'red.' Older adults typically have more difficulty with this task than young adults, suggesting less efficient inhibitory processes. However, when the to-be-named color and color word are separated in space, inhibition of the color word appears to operate comparably in young and older adults. Together, these results suggest that age-related declines in the efficiency of inhibitory function seem to be modulated by task parameters that affect the ease of discriminating between relevant and irrelevant information.

Negative priming is another procedure that was thought to offer an index of efficiency of inhibitory function. Indeed, negative priming was one of the most common tests of age-related inhibitory decline in the 1990s. In this procedure, which involves targets and distractors, a distractor stimulus that is to be ignored on one trial becomes the to-be-attended stimulus on the subsequent trial. Empirically, it has been observed that responding is slowed in the trial sequence just described relative to a sequence in which there is no relationship between targets and distractors on subsequent trials. This lengthening or reaction time is termed negative priming. The initial theoretical interpretation of this phenomenon is that because the distractor stimulus is inhibited on the initial trial, processing that same stimulus on the subsequent trial will take longer because the effects of the previous inhibition will have to be overcome. Within this interpretation, the magnitude of the slowing, or negative priming, is then used to index the strength of inhibitory function. Subsequent work, however, has shown that the negative priming effect

can also be interpreted in terms of episodic retrieval processes, or in terms of a mismatch in a target/distractor tagging process. Because it is very difficult to disentangle these potential interpretations of age differences, negative priming has been virtually abandoned in the cognitive aging literature as a measure of inhibitory function.

Eye Movements

Although it still has a relatively small literature, eye movement technology has also been used to examine inhibitory function in young and old adults. For example, in the antisaccade task, participants are instructed to suppress the prepotent tendency to look toward a sudden-onset visual stimulus but to look in the opposite direction instead. The timing, extent, and direction of eye movements are measured using technology designed to reveal direction of gaze on a moment-by-moment basis. Because voluntary eye movements have been shown to be under the control of brain areas including the dorsolateral prefrontal cortex, the antisaccade task has been viewed as an index of both behavioral inhibition abilities and the integrity of the brain structures that underlie those abilities. Findings indicate that older adults are less successful at the antisaccade task than young adults because they have difficulty suppressing the strong tendency to first look toward the stimulus before they move their eyes in the opposite direction. These findings reveal an age-related inhibitory deficit that is mediated by the DLPFC. Eye movement technology is a powerful tool for evaluating hypotheses related to attention and aging; assuming the direction of gaze reflects the focus of attention, such technology can provide more direct measures of attention and distraction than are possible, for example, using only reaction time measures.

Working Memory

Inhibitory processes have also been hypothesized to play an important role in working memory and related language functions as they change with age. Inhibitory processes are assumed to limit the activation of semantic information for the task at hand. If inhibitory processes are operating at suboptimal efficiency in older adults, then irrelevant information may be activated and may serve to functionally reduce the capacity of working memory by unnecessarily taking up space there.

Studies using language materials with ambiguous interpretation have been used to test these ideas about inhibition, working memory, and language function. For example, ambiguous prose that might be interpreted in two or more ways is presented, followed by disambiguating information. Inhibitory efficiency is indexed by measures of the availability of the incorrect interpretation in working memory. This availability may be measured in priming tasks or implicit memory tasks. Several studies have shown that irrelevant information remains active longer in older adults than in young adults, reducing working memory capacity and decreasing the efficiency with which language information can be processed. It has been proposed that declining inhibitory function is responsible for these age-related changes. However, this conclusion remains controversial; on the basis of reinterpretation of these findings along with new findings, other reviewers have concluded that there is relatively little evidence for an age-related inhibitory deficit in language processing (*see* Memory).

Inhibition in the Social Arena: Verbal Communication

Inhibition not only suppresses selected inputs but also acts to control such outputs as inappropriate behaviors, which might otherwise interfere with normal social interactions. One area in which altered inhibitory function might affect social interactions is verbal communication. There is some evidence suggesting that older adults are more likely than young adults to exhibit off-target verbosity in conversation or related forms of communication. Older adults appear to be more vulnerable to the intrusion of personal experiences and memories into consciousness. Instead of gating out this information, they may include it in social exchanges regardless of its relevance to the topic at hand. One outcome of this verbosity might be reticence on the part of others to engage a verbose individual in conversation, which contributes to some level of social isolation of the verbose person. Thus, inhibitory deficits, if truly contributory to this pattern of interactions, can have negative consequences for the social well-being of older individuals.

Studies including measures of both off-target verbosity and psychometric measures of inhibitory processes have indicated a relationship between the two. That is, those individuals who score higher on verbosity measures do less well on the measures of inhibitory function. Although this relationship suggests a causal role for altered inhibitory efficiency in communication verbosity, other factors may also play a role. An individual's expectations about the constraints on the conversation, the relationship between conversation participants, and lifelong conversation patterns may all influence the direction a conversation may take. Specifying the precise role of

inhibitory processes remains for further study (*see* Language and Communication in Aging).

Inhibition in Mental Health: Selective Processing of Information

A number of mental health problems have been associated with reduced attention control. For example, in obsessive-compulsive disorder, depression, and schizophrenia it has been suggested that the intrusion of irrelevant or unwanted material into consciousness may contribute to cognitive inefficiency and/or psychological distress. Cognitive theories of depression hold that depressed individuals may be besieged by negative thoughts that overpower normal inhibitory processes. The depressed individual thus perceives or recalls primarily negative information, which in turn perpetuates the depressive episode. Although this view of depression is still controversial, a variety of studies using tasks such as the Stroop task are consistent with the hypothesis that depressed individuals have less efficient inhibitory control. The data on whether this deficit is exacerbated by age-related declines in inhibitory control are also a matter of some controversy. Among the few studies that have addressed this question, some report no greater deficits in older depressed individuals, whereas others have suggested that aging and depression have interactive effects to produce the greatest negative impact on behavior. Clearly, more work needs to be done to answer this important question regarding the combined effects of aging and depression on inhibitory function (*see* Depression).

Inhibitory dysfunction has also been identified as a fundamental component of the cognitive deficits associated with schizophrenia. Inhibition has been studied in individuals with schizophrenia using procedures similar or identical to those used to assess age effects: physiological orienting and habituation, negative priming, sensory gating, the Stroop task, and continuous performance tasks. The pattern of results indicates that inhibitory deficits in older adults and in individuals with schizophrenia are very similar. Unfortunately, very few studies have explicitly examined the combined effects of aging and schizophrenia on inhibitory function. Data from the few studies that have been conducted suggest that the deficits seen in older schizophrenics are greater than those seen in either normal aging or schizophrenia alone. Again, however, more work needs to be done before any strong conclusions can be drawn about the combined effects of aging and schizophrenia on inhibition in cognitive function (*see* Mental Health).

Summary and Conclusions

A variety of studies have provided evidence suggesting that inhibitory function declines with advancing age. However, a number of issues must be considered before any global statement can be made about aging and inhibitory function. For example, inhibitory processes can be observed at many levels of nervous system function, from synaptic connections to overt behavior. Evidence indicates that there are multiple types of inhibition and/or multiple inhibitory mechanisms that may play a role in age differences in inhibitory function. Age differences are observed on some tasks but not others. A fuller understanding of inhibitory function in aging requires the development of specific models that can integrate these various findings and that can be put to empirical test.

A second issue concerns the validity of measures of inhibitory function. In many cases, tasks that are assumed to measure inhibition need to have that assumption tested. The case of negative priming is a good illustration of tasks whose outcome is open to multiple interpretations. Most data collected with such tasks are not useful for evaluating inhibitory function, and much care is needed in order to assure the validity of assessments of inhibitory function.

And finally, individual differences in inhibitory function across age groups need to be understood and explained. Age does not perfectly predict inhibitory efficiency, and the other relevant factors must be identified in order to better understand the contribution of inhibitory function to cognitive aging.

See also: Attention; Depression; Language and Communication in Aging; Memory; Mental Health.

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Intelligence

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that development of intellectual abilities can be mapped onto biological versus cultural ensembles of influence.

Glossary

Covariance Dedifferentiation – Stronger associations between the fluid mechanics and the crystallized pragmatics in old age as compared to young adulthood.

Crystallized Pragmatics – Content-rich abilities strongly driven by cultural systems of influence; typical examples are verbal knowledge and professional expertise.

Directionality Dedifferentiation – Decline in both the fluid mechanics and the crystallized pragmatics seen in very old age.

Fluid Mechanics – Abilities representing measurable outcomes of biological influences on intellectual development; basic information processes that are content poor and universal, such as processing speed and working memory.

Terminal Decline – Changes in intelligence associated with impending death. These changes may reflect causal structures other than those underlying normative age-graded changes, including cognition-influencing diseases.

Two-Component Models of Life Span Cognition – Models of intelligence disputing the existence of a unitary general intelligence construct and positing

Introduction

This article summarizes psychometric theorizing and evidence about intelligence in old age, with a focus on normal aging. First, two-component theories of life span changes in intelligence are introduced, and evidence regarding average population age gradients in intellectual abilities is summarized. Then, hypothesized normative and basic determinants of decrements in intellectual performance in old age as well as the extent and possible causes of individual differences in such decrements are reviewed. Finally, evidence is highlighted suggesting that many aging individuals possess sizable capacity for learning and plasticity, despite aging-related losses in average intellectual performance.

Two-Component Models of Life Span Changes in Intelligence

Two-component models of life span changes in intelligence posit that development of intellectual abilities can be mapped onto biological versus cultural ensembles of influences (see **Figure 1**). Typical contemporary examples for two-component models are the distinction between fluid and crystallized intelligence advanced by Raymond B. Cattell and John

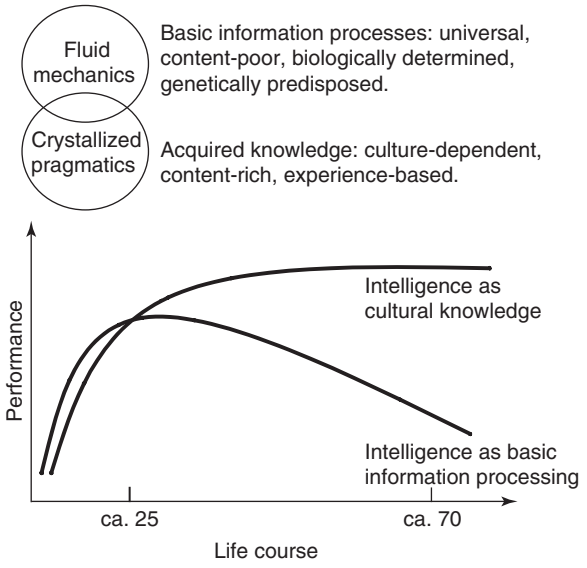

Figure 1 Two-component models of cognition. The top section defines the two categories of intellectual abilities and the bottom section illustrates postulated life span trajectories. In very old age, the trajectories become less differentiated because the fluid mechanics increasingly constrain the acquisition, expression, and representation of pragmatic knowledge.

Horn and the decomposition of cognition into mechanics and pragmatics proposed by Paul Baltes. Two-component models of life span changes in intelligence have a long history dating back to Johann Nicolaus Tetens (1736–1807), a philosopher and psychologist of the enlightenment era who noted that well-trained skills are less likely to decline with advancing age than the basic abilities underlying their acquisition. Thus, and most importantly, two-component theories dispute the validity of a unitary general intelligence construct in understanding intellectual development across the life span. Instead, at least two broad, ontogenetically intertwined but separable categories of abilities are needed to describe the basic properties of intellectual development.

The first collection of intellectual abilities represents measurable outcomes of the influence of the biological component on development. It manifests itself in cognitive processes involving extrapolation, reorganization, and transformation of novel information (i.e., reasoning) and in basic information processes such as working memory (i.e., the ability to maintain information online while manipulating it), processing speed (i.e., the speed with which elementary processing operations can be performed), and cognitive control (i.e., the top-down coordination and control of lower-level processing). Henceforth, these processes are referred to as the fluid mechanics of intelligence.

The second, more disparate category of intellectual abilities refers to procedural and declarative knowledge common to a given culture (e.g., verbal knowledge), but also to specialized and sometimes highly idiosyncratic (person-specific) knowledge such as occupational expertise, as well as to knowledge about the meaning and conduct of life. Henceforth, these processes are referred to as the crystallized pragmatics of intelligence. For examples of specific abilities and functions related to each of the two components, see **Figure 2**.

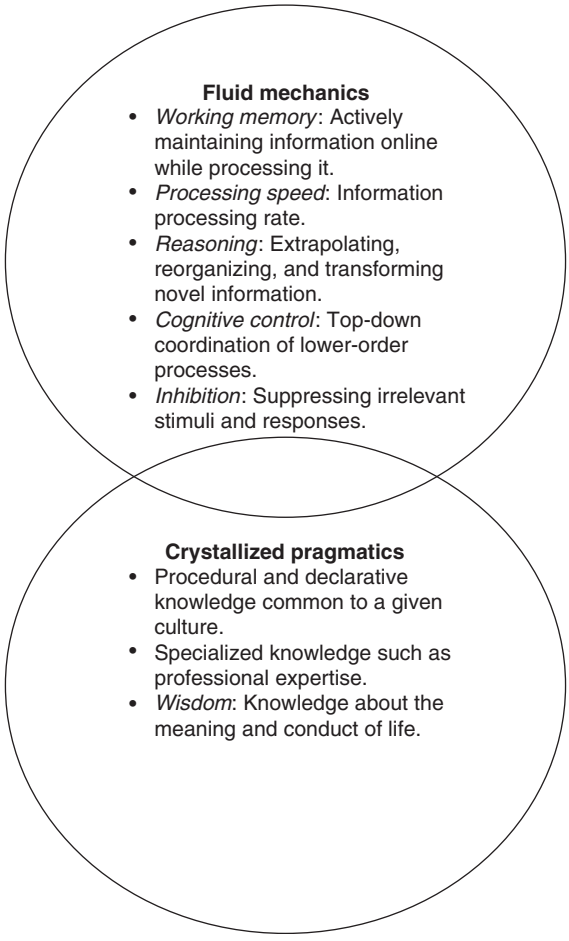

Figure 2 Exemplary functions and abilities in the broad domains of the fluid mechanics and the crystallized pragmatics.

Average Aging Patterns of Fluid Mechanics and Crystallized Pragmatics

The fluid mechanics are expected to decline after maturity. In contrast, the crystallized pragmatics are proposed to increase over the life span as long as knowledge maintenance and knowledge acquisition outweigh the adverse consequences of losses in the mechanics (see **Figure 1**). Empirical evidence is largely consistent with these propositions. Starting in young or middle adulthood, cross-sectional evidence

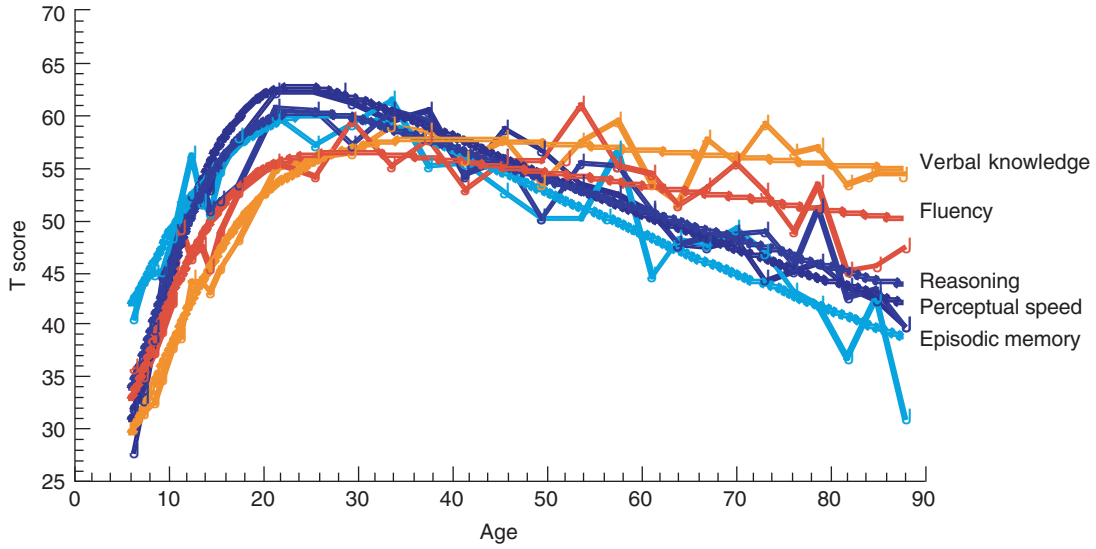

Figure 3 Cross-sectional life span age gradients for five different intellectual abilities. Verbal knowledge is a marker of intellectual ability from the domain of the crystallized pragmatics, whereas reasoning, perceptual speed, and episodic memory are intellectual abilities from the domain of the fluid mechanics. Fluency is generally regarded as a hybrid intellectual ability because it requires fast access to stored knowledge. The empirically observed age gradients are consistent with two-component theories of life span cognition. Adapted from Li S-C, Lindenberger U, Hommel B, Aschersleben G, Prinz W, and Baltes PB (2004) Transformations in the couplings among intellectual abilities and constituent cognitive processes across the life span. *Psychological Science* 15: 158.

reveals continuous decrements for abilities in the broad fluid domain. Age gradients in the domain of the crystallized pragmatics show greater variation within and between individuals in the transition from early to late adulthood, with the modal patterns of increments in young adulthood typically followed by asymptotic plateaus in middle and late adulthood, until modest decrements are discernible in old age (e.g., around 60–80 years of age) or very old age (e.g., over 80 years of age). For illustration, see **Figure 3**.

The maintenance of levels of intellectual performance in abilities belonging to the crystallized pragmatics well into old age is not confined to psychometrically assessed intellectual abilities from this domain such as verbal knowledge. Rather, maintenance is also observed for specialized and person-specific bodies of knowledge and for knowledge about the meaning and conduct of life. For example, reasoning about difficult life problems (e.g., a 14-year-old pregnant girl seeking advice) is unrelated to chronological age from early adulthood up to old age, and older individuals with an idoneous constellation of enabling personality dispositions, life experiences, and cognitive styles are among the top performers.

Longitudinal findings suggest a greater degree of similarity between the age gradients of the fluid mechanics and the crystallized pragmatics than cross-sectional evidence. Here, the fluid mechanics show decelerating increases across young adulthood, peaks in middle age, and accelerating declines thereafter. The dominant pattern of the pragmatics is one of stable, or even increasing, performance until old or very old age. Note, however, that longitudinal findings are often obtained from individuals who show more positive changes than the population from which they originate, and that retest effects may further bias age gradients in the positive direction.

In summary, and as predicted by two-component theories of life span cognition, available evidence underscores the multidirectionality of adult intellectual development. Considerable decline in the fluid mechanics and stability followed by late-life decline in the crystallized pragmatics constitute the classical pattern of the aging of adult intelligence.

The Dedifferentiation Hypothesis

The onset and amount of decline in the crystallized pragmatics during the transition from old to very old age is more variable than the divergence in age gradients between the fluid mechanics and the crystallized pragmatics observed during earlier periods of the life span. Whereas some studies report small negative age trends in crystallized pragmatics during early old age, with noticeable decrements appearing only at later ages, others report age-related decrements starting at about age 50. There is general agreement, however, that the preservation of crystallized pragmatics often observed for groups of older adults does not generalize to groups of very old

individuals. That is, for the period from early to late adulthood, cross-sectional evidence reveals monotonic decline in the fluid mechanics but stable or increasing performance levels for the crystallized pragmatics. However, in very old age, negative age gradients generally prevail for both the fluid mechanics and the crystallized pragmatics. Hence, in very old age, the difference in the directionality of the age gradients diminishes and eventually ceases to exist. In relation to the life span development of the fluid mechanics and the crystallized pragmatics, this pattern has been termed directionality dedifferentiation. Importantly, this pattern of directionality dedifferentiation also holds for longitudinal data. Furthermore, age-associated changes in the structure of intelligence are consistent with the notion of stronger relations among different intellectual abilities in old age relative to early adulthood. This finding has been referred to as covariance dedifferentiation.

A long-standing hypothesis in life span developmental research asserts that the functional organization of intellectual abilities undergoes decompression (differentiation) during maturation and again becomes more compressed (dedifferentiated) in old age. The differentiation-dedifferentiation hypothesis promotes a dynamic and process-oriented view of the structure of intellectual abilities. During childhood and old age, the operations and expressions of the diversity of cognitive abilities are posited as being constrained by the developmental status of the biological substrates of intelligence. In contrast, during maturation and in adulthood, biological-developmental constraints are relaxed, and other factors, such as interest and educational opportunities, occupy more prominent roles as determinants of individual differences in intellectual performance and development, leading to greater diversity in levels of functioning in different abilities. In old and very old age, the space of intellectual abilities becomes again increasingly dominated by an ensemble of common biological constraints on intellectual development. In terms of the two-component view of life span intelligence, old age decrements in abilities belonging to the domain of the crystallized pragmatics are induced by decline in the fluid mechanics. Put differently, the biological changes indicated by declines in the fluid mechanics hinder the acquisition, expression, and representation of pragmatic knowledge in old age when falling below thresholds that may vary from skill to skill. Conversely, at higher levels of functioning, development of the crystallized pragmatics is more dependent upon cultural-experiential factors, though biological factors continue to play a role.

The dedifferentiation hypothesis was sparked by early findings of increasing associations among different intellectual abilities from early adulthood to old age. More recent empirical evidence has generally bolstered the early findings, but some prominent exceptions are also available. Importantly, recent findings by Paolo Ghisletta and Ulman Lindenberger support the specific account of the dedifferentiation hypothesis, suggesting that decline in the fluid mechanics ultimately limits the acquisition, expression, or maintenance of the pragmatics in old age and thus drives late-life decline in the crystallized pragmatics. It follows that, with advancing adult age, between-person differences in levels of crystallized pragmatics, such as verbal knowledge, are increasingly determined by the functioning of the fluid mechanics, such as processing speed. Thus, in old age, expressing, maintaining, and acquiring knowledge are more and more dependent on biological vitality.

Basic Determinants of Decline in Fluid Mechanics

If decline in the fluid mechanics drives late-life decline in the crystallized pragmatics, then what drives decline in the fluid mechanics? Recent decades have witnessed a great number of predominantly cross-sectional studies attempting to identify information-processing mechanisms that act as domain-general pacemakers of decline in the fluid mechanics in old age. Among the most prominent constructs are processing speed, working memory capacity, and the ability to suppress irrelevant information (inhibition). Evidence supporting each of these three constructs as primary determinants of decline in a wide variety of fluid mechanics is available. However, all three constructs are relatively weakly grounded at the neurophysiological level, suffer from difficulties in making differential predictions, and often have been investigated in age-heterogeneous cross-sectional data sets, which are severely limited in inferential conclusiveness. Strengthening the link between aging changes at behavioral and neuronal levels of analysis probably offers a more viable route toward the identification of domain-general mechanisms of decline in the fluid mechanics.

In this vein, the emerging field of the cognitive neuroscience of aging has highlighted the central role of adult age changes in neuromodulation for intellectual aging. In particular, theoretical work by Shu-Chen Li and colleagues using neurocomputational modeling has suggested that age-based reductions in levels of the neurotransmitter dopamine is

apt to explain key phenomena of intellectual aging such as decrements in mean levels of performance, greater age deficits with more difficult tasks, lower maximum levels of performance, as well as increments in covariation between tasks across individuals, performance fluctuation, and interindividual differences. In addition, there are strong empirical relations among dopamine markers, adult age, and intellectual performance.

Morphological alterations and decreases in brain volume of the prefrontal cortex also have been associated with normal aging. Given that brain activity in the prefrontal cortex is functionally related to performance in central abilities of the fluid mechanics, such as reasoning and working memory, these findings suggest that anatomical, chemical, and functional changes in the prefrontal cortex and associated neuronal circuitries play a central role in late-life intellectual decline. Brain alterations in the medial temporal lobe and diencephalic systems are observed to a lesser extent with normal aging and appear to be more specifically linked to the onset and progression of age-associated dementing illnesses.

Normative and Non-normative Influences on Intellectual Development in Old Age

Average age gradients and the search for basic determinants of cognitive decline in old age serve important purposes. However, to understand the development of intelligence in old age, it is necessary to unpack the ingredients contributing to a particular score, for a particular individual, at a particular point in time. Intellectual development in old age is shaped by a wealth of additional developmental sources such as learning history, health status, distance from death, onset of pathology, and non-normative events, all of which are only loosely linked to chronological age. Thus, as suggested by Paul Baltes and others, three distinct but overlapping influences on intellectual changes in old age need to be set apart: normative age-graded influences, normative history-graded influences, and non-normative (idiosyncratic) influences. Normative in this context refers to influences that are relatively general to the population of aging individuals, such as declines in basic determinants of the fluid mechanics. Age-graded influences refer to those biological and environmental factors that are highly related to age and therefore shape the intellectual aging processes of most individuals. History-graded influences differ across birth cohorts, historical periods, or both. For example, substantial associations between birth cohorts and intelligence scores have been observed during the past century at the age of enrollment into military services. Finally, non-normative influences are more or less individualized conditions and events (e.g., rare illnesses, winning a lottery).

Between-Person Differences in Old-Age Intellectual Change: Risk and Protective Factors

Differences in intellectual performance between individuals are pronounced in groups of older individuals. In addition to stable differences in levels of intellectual performance, which are large throughout life, between-person differences in intellectual changes are also substantial within old age and are actually more pronounced in old age than during earlier periods of the adult life span. Furthermore, for the periods of old and very old age, between-person differences in change tend to be greater for the fluid mechanics than for the crystallized pragmatics, suggesting a predominantly biological origin. The following sections list some of the causal factors that contribute to the diversity of developmental patterns in intellectual functioning observed in old and very old age.

Terminal Decline

One important source of between-person differences in intellectual development in old age is terminal decline, denoting changes associated with impending death. These changes may reflect causal structures other than those underlying normative age-graded changes, for example, specific cognition-influencing diseases or global breakdowns of the biological system. Mounting evidence points to an association between performance on intelligence tests and longevity as well as between changes in intelligence and mortality. Importantly, directionality dedifferentiation might be driven by a subset of individuals in close proximity to death. Put differently, in a person entering the terminal decline phase, the crystallized pragmatics may grow increasingly dependent on the fluid mechanics, whereas the intellectual ability structure of a person of the same age who is more distant from death may remain more differentiated.

The existence of mortality-related changes in intelligence is suggestive of profound heterogeneity in development and warns against the uncritical practice of averaging individual differences in intelligence over a particular age. Average trends based on groups that are made up of mixtures of different types of individuals may yield a picture of intellectual development in old age that approximates, at best, an unknown proportion of the individuals constituting

this mixture. Thus, a focus on the individual, or at least on subgroups of individuals, is needed to understand intellectual development in late adulthood and old age. In the case of distance to death, aging-related changes and dying-related changes are confounded when performances of relatively healthy individuals and individuals experiencing terminal decline are averaged. Of course, if some of the causal structures promoting intellectual decline in old age are indeed mortality related, one would expect most individuals to sooner or later evince a pattern of dedifferentiation; that is, from a life span perspective, normally aging and terminally declining individuals do not denote mutually exclusive groups, but different sections of a developmental pathway.

Preclinical Dementia

Dementing illnesses, such as dementia of the Alzheimer type, are often preceded by a prolonged preclinical phase. During this period of time, dementia-related cognitive deficits are present but have not yet reached a diagnostic threshold. For instance, cognitive impairments several years prior to diagnosis have been shown to be sensitive markers of later dementia diagnosis. Preclinical cognitive deficits tend to be global, with impairments in episodic memory apparently being most prominent. Furthermore, impairments in functions that are normally relatively well preserved in old age, such as the crystallized pragmatics, may distinguish early dementia from aging. Given the accelerating increase of dementia incidence in old age, the proportion of individuals with preclinical dementia in the population is also bound to increase. This age-associated increase in the proportion of individuals suffering from preclinical dementia has led researchers to reconsider conclusions about normative age-related changes in intelligence. In analogy to removing individuals with terminal decline, removing individuals who later will develop dementia reduces the estimated size of the negative relation between intellectual performance and age.

Other Diseases

Many specific health-related conditions that affect intellectual performance increase in old age. Much research has addressed the effects of disorders to the circulatory system on intellectual performance. In general, this research has shown that circulatory disturbances, ranging from hypertension and cardiovascular conditions to stroke and vascular dementia, have profound effects on the brain and intellectual performance, especially in the fluid mechanics. Medial-temporal structures such as the hippocampus and related intellectual functions such as episodic memory appear to be especially sensitive to cardiovascular conditions including hypertension.

Elderly adults with diabetes tend to evince impaired intellectual performance. Furthermore, non-diabetic older individuals who have impaired glucose tolerance tend to show similar but less pronounced impairments in performance. Thus, there might be a continuum of intellectual performance deficits in diabetes that progresses from subclinical to the clinical phase.

As in earlier age periods, depression is related to lower performance on intelligence tests in old age. Again, the severity of depressive symptoms is related to intellectual performance, with individuals suffering from depressive symptoms performing at higher levels than clinically depressed individuals but at lower levels than non-symptomatic individuals.

Finally, various markers related to nutrition show an association with intellectual performance in old age. For example, relatively small (e.g., subclinical) deficiencies in vitamin B_{12} and folic acid appear to negatively affect intellectual performance.

Engaged Lifestyle

On the positive side, older individuals living an engaged and active life on average perform better on tests of intelligence than less active individuals. In addition, changes in intellectual performance in old age are associated with changes in lifestyle factors, such as engagement in leisure activities, activities in a social context, and intellectually stimulating activities. When analyzing longitudinal data from the Berlin Aging Study with dynamic modeling techniques, Martin Lövdén, Paolo Ghisletta, and Ulman Lindenberger recently provided direct evidence for the widely held but untested assumption that staying mentally and socially active attenuates intellectual decline in old and very old age.

The mechanisms through which engaged lifestyles influence intellectual development in old age are not yet well understood. The disuse hypothesis proposes that changes in lifestyle during old age (e.g., retirement, loss of spouse, and subsequent social isolation) may result in reduced levels of mental stimulation and subsequent magnification of cognitive decline. The cognitive reserve hypothesis asserts that life experiences during earlier periods of the life span, such as educational attainment, provide greater readiness for compensatory changes in response to age-related and disease-related neurophysiological decline and thus contribute to the resilience of late-life intelligence. Finally, lifestyle factors may also modify the course of neurophysiological changes underlying intellectual aging in more direct ways. For instance,

mechanisms of neuronal plasticity (see below) may function more efficiently in individuals with engaged lifestyles.

Most likely, several of these causal paths are operating in concert. Some of the behaviors associated with engaged lifestyle, such as physical activity and healthy nutrition, may reduce age-related negative influences on non-neural components of the brain, such as vascular changes including decreased blood flow, oxygen extraction, and glucose transport. For instance, mental stimulation may directly influence neurophysiological processes, whereas physical exercise may improve brain functioning indirectly but effectively through the cardiovascular route. Recent evidence based on animal models suggests that the two forms of stimulation may interact and reinforce each other.

Genetic Influences

Examination of associations between genetics and intellectual functioning in late life has been divided into two types. One class of studies has examined the overall influence of genetic variation by comparing dizygotic and monozygotic twins. In general, heritability in intellectual functioning (i.e., between-person differences accounted for by genetic differences) increases from about 35% during childhood to about 80% in middle adulthood. In old age, heritability tends to decrease to about 60%, perhaps pointing to a gradual breakdown of genome expression during the postreproductive period of the human life span. The other class of studies has focused on the role of specific genetic polymorphisms on intellectual functioning in old age. Here, the gene coding for the apolipoprotein E (APOE) has received most attention because carriers of a variant of this gene are considerably more likely to develop dementia. Even in samples of older adults screened for dementia, genetic variations in the APOE polymorphism are related to intellectual functioning. It remains to be seen whether this association reflects the presence of preclinically demented individuals. The influence of genetic variations on individual differences in neuronal organization and intellectual functioning is likely to become an active area of research in coming years.

Intellectual Plasticity in Old Age

Intellectual plasticity, or the ability to improve one's intellectual performance through experience (e.g., learning), continues to be present in healthy old age. For instance, training programs targeted at intellectual performance in the domain of the fluid mechanics do indeed lead to performance improvements. However, training gains are considerably smaller in older adults than in young adults. For instance, after instruction and training in a mnemonic technique for the recall of word lists, the distributions of young and older adults' memory performances become close to non-overlapping. In very old age, training gains are further restricted in size and compromised in quality.

Intellectual plasticity in old age probably reflects, for the most part, reactivation of existing and, to some extent, acquisition of novel intellectual strategies, rather than modification of fluid mechanic efficiency per se. As a consequence, positive transfer of training gains in a specific intellectual task to other tasks from the same or related intellectual abilities is generally small or absent. On a more promising note, recent aerobic fitness interventions with healthy older adults have been found to positively affect performance on a range of cognitive tasks that impose high demands on executive functions or cognitive control, that is, on mechanisms that are at the heart of the fluid mechanics. These positive changes appear to be accompanied by structural and functional alterations in relevant parts of the brain such as areas in the prefrontal cortex. Future research needs to further examine the amount, mechanisms, and moderators of neuronal and behavioral plasticity in late adulthood and old age.

Conclusion

Intelligence is a multidimensional construct that undergoes structural transformation from early to late adulthood and advanced old age. Two-component theories of life span intelligence posit two broad systems of influence, one biological and the other cultural. In early adulthood, the biology-based fluid mechanics and the culture-based crystallized pragmatics of intelligence are loosely coupled and display different age gradients, with decline for the fluid mechanics and stability or increase for the crystallized pragmatics. In old and very old age, declines in the fluid mechanics compromise the acquisition, expression, and representation of the pragmatic knowledge. The onset and nature of this transition differ from person to person and may be more dependent upon distance from death or cognition-related pathology than upon distance from birth. In the course of their lives, individuals experience unique constellations of normative, age-graded, and nonnormative influences. Intelligence is not necessarily structured similarly in different individuals just because they happen to be born at similar points in time. General regularities across groups of aging individuals in patterns of intellectual change in old and very old age can be discerned after sources of individual differences, such as

age-related pathology and terminal decline, have been identified and taken into account. Thus, understanding intellectual development in old age requires a multivariate, dynamic, and person-centered perspective.

See also: Information Processing/Cognition; Learning; Life Span Theory.

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International Perspective on Gerontology

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Glossary

HelpAge International (HAI) – A global network of not-for-profit organizations whose mission is to work with and for disadvantaged older persons.

International Association of Gerontology and Geriatrics (IAGG) – National multidisciplinary societies concerned with research and training in gerontology and geriatrics.

International Association of Homes and Services for the Ageing (IAHSA) – Links organizations and individuals providing services for older persons, including shelter care as well as services designed to enable seniors to remain in the community.

International Federation on Ageing (IFA) – More than 100 organizations representing or serving older persons at the grassroots level including government agencies, for-profit groups, and individual members.

International Longevity Centers (ILCs) – A Network of independent, not-for-profit think tanks established to assist individuals and societies to address increased longevity and population aging in positive and productive ways and to highlight the contributions of older persons to their family and nation.

International Network for Prevention of Elder Abuse (INPEA) – Includes representatives from 12 countries with a commitment to worldwide prevention of elder abuse.

International Psychogeriatric Association (IPA) – Individuals and organizations whose direct concern is the mental health of the elderly, including representation from 67 countries.

Introduction

For the last several decades, international gerontology has largely centered on the activities of a relatively small number of non-governmental organizations (NGOs) that link organizations and individuals across the world that have aging and the aged as their primary focus. These NGOs include multidisciplinary professional associations such as the International Association of Gerontology and Geriatrics; specialized professional associations and networks such as the International Psychogeriatric Association and the International Network for Prevention of Elder Abuse; and advocacy/relief organizations such as the International Federation on Ageing, HelpAge International, and Help the Aged. More recently, the International Longevity Centers, a network of independent think tanks, has emerged. Paralleling these, disease-specific advocacy/support organizations such as Alzheimer's Disease International and the International Osteoporosis Foundation have been established, as well as federations of senior citizens' organizations such as the International Federation of Senior Citizens Organizations, the European Federation of Older Persons, and AGE, The European Older People's Platform.

This article begins with a description of selected international NGOs focused on aging, arranged chronologically in order of their establishment. This is followed by a description of key United Nations (UN) activities and agencies concerned with aging issues, which comprise the second major component of international gerontology. These include the 1st and 2nd World Assemblies on Ageing, the 1st NGO World Forum on Ageing, the UN Programme on Ageing, the World Health Organization's Ageing and Life Course Programme, and the International Institute on Ageing, UN–Malta. The article ends with a brief description of some international educational initiatives in gerontology/geriatrics and speculation on future developments of the field at the international level.

International NGOs Focused on Aging

International Association of Gerontology and Geriatrics (IAGG)

The IAGG, the primary international multidisciplinary professional association in the field, was formed and registered in Liege, Belgium in 1950 as the International Association of Gerontological Societies. Several years later it became known as the International Association of Gerontology (IAG), a name it held until 2005, when, reflecting changes in its composition over the years, its name was changed to the International Association of Gerontology and Geriatrics (IAGG). Members of the IAGG are national multidisciplinary societies concerned with research and training in gerontology or geriatrics. Until 2005, with the exception of the United States and United Kingdom, only one society per country was admitted to membership. Currently, the IAGG has 71 member organizations, in five regions and 64 countries, with a combined membership of over 46 000.

The objectives of the IAGG are the promotion of gerontological and geriatric research, training in the field of aging, and interests of member organizations in international affairs. These objectives are accomplished through special projects, a newsletter, a World Congress held every 4 years, as well as regional congresses that take place midway between World Congresses. The first World Congress of IAGG was held in Liege, Belgium in 1950. The next two, which will be the 19th and 20th, will take place in Paris, France in 2009 and in Seoul, Korea in 2013.

The IAGG is governed by a council consisting of representatives from each member society, their number determined by a formula based on the number of members enrolled in the society. The Executive Committee, consisting of the President, Secretary-General, Treasurer, Past-President, President-Elect, as well as regional chairpersons for Asia-Oceania, Europe, North America, and Latin America and the Caribbean, hold office for the period starting with the end of each World Congress and extending to the beginning of the next. The secretariat also

changes location every 4 years, moving to the country of the president.

The IAGG is a category III NGO with respect to the UN. At this level, the organization is recognized as a consultative source that can influence policy decisions. The IAGG is regularly consulted by both the UN Programme on Ageing and the World Health Organization's Ageing and Life Course Programme as well as other UN agencies such as the International Labor Organization, Pan American Health Organization, United Nations Development Program, and United Nations Population Fund. It has partnered with these organizations in the development of key programs, publications, and conferences. Recent examples include the *Research Agenda on Ageing for the 21st Century* and the Valencia Forum, an international scientific conference held immediately before the 2nd World Assembly on Ageing.

International Federation on Ageing (IFA)

The IFA was established in 1973. Its current membership includes more than 100 NGOs representing or serving older persons at the grassroots level, government agencies, for-profit groups, as well as individual members. Sixty-two countries are represented in its membership. Through its project and advocacy work, it seeks to influence and promote positive change for older people globally.

There are two categories of membership: full members and associate members. Full members comprise local, regional, provincial/territorial, or national non-governmental associations, including for-profit organizations, working with or representing the interests of older people. Fees vary according to the annual operating budget of the organization. Associate members may be individuals or groups but do not have voting privileges.

Since 1993, the IFA has held biennial global conferences. Its information dissemination activities also include two regular publications: *Intercom*, a newsletter that focuses generally on policy and practice and their impact on older persons and describes ongoing activities of the IFA and its affiliates, and *Global Ageing: Issues and Actions,* which devotes its two issues per year to special topics (e.g., in 2005 issue 1 was focused on elder abuse and neglect and issue 2 on Latin America's place in global aging).

The governing structure includes three elected officers (President, Vice-President, and Past-President) and a 16-person board of directors. Paid staff of the permanent secretariat, located in Montreal, Canada include a Secretary General, a Director of International and Corporate Relations, and two project officers.

International Psychogeriatric Association (IPA)

Founded in 1982, the IPA is composed of individuals and organizations whose direct concern is the mental health of the elderly. Membership was approximately 1200 in 2006, with representation from 67 countries. Individual members include psychiatrists, psychologists, nurses, primary care physicians, occupational therapists, social workers, and other health-care professionals. The IPA's objectives are to promote research and education, facilitate an international exchange of ideas on psychogeriatric issues, and foster cross-cultural understanding of the latest developments in the field. These objectives are achieved through publication of the *IPA Bulletin* and the journal *International Psychogeriatrics* as well as by hosting an International Congress every 2 years. Additionally, regional meetings are convened annually or biennially.

The IPA is governed by a 20- to 25-member Board of Directors, no more than two of whom reside in the same country. Individual members, like full members, pay dues, may hold office, and have full voting rights. Organizations or institutions wishing to exercise voting rights must designate an individual as its representative. The IPA's registered office is in Illinois.

It maintains relationships with many regional, national, and international organizations, including the World Health Organization, the World Psychiatric Association, Alzheimer's Disease International, the European Association of Geriatric Psychiatry, IAGG, and the World Federation of Neurology.

HelpAge International (HAI)

Established in 1983, HAI is a global network of not-for-profit organizations whose mission is to work with and for disadvantaged older persons. This is accomplished by supporting programs, giving a voice to older persons, and influencing policy at local, national, and international levels. Originally formed by agencies in five countries (Canada, Colombia, India, Kenya, and the UK), the HelpAge network now consists of more than 70 affiliated organizations in 50 countries.

HAI has two regular publications, both published twice a year: *Ageways*, which features practical information on aging and development, particularly good practices developed by affiliated organizations, and *Ageing and Development,* which is targeted to policy makers, program planners, and researchers concerned with development and poverty reduction. Additionally, regional newsletters are published three or four times a year. These include *Aging in Africa*, *AgeNews Asia/Pacific*, *Kyrgyzsian Newsletter,* and *Moldova Newsletter.*

HAI is governed by a Board of Trustees, which includes representatives of affiliated organizations. It has a secretariat with offices in London, Brussels, and the United States, maintains five regional centers (in Africa, Asia/Pacific, Latin America, the Caribbean, and Eastern Europe/Central Asia), and supports seven national programs and a number of emergency programs.

International Association of Homes and Services for the Ageing (IAHSA)

IAHSA, founded in 1994, links organizations and individuals providing services for older persons. These include shelter care options (e.g., independent living, assisted living, hostels, group homes, nursing homes, retirement villages) as well as services designed to enable seniors to remain in the community (e.g., adult day care, home care, home nursing). While IAHSA is a non-profit organization, its membership includes all ownership types, including profit, not-for-profit, and governmental, ranging from single-site facilities to associations representing large numbers of service providers. The IAHSA network extends to over 12 000 service providers in approximately 30 countries.

Three major foci for IHASA are the workforce, technology, and new care models. Activities include organizing an international conference every 2 years and partnering with other organizations on special projects. IHASA has an ongoing relationship with the Center for Aging Services Technologies (CAST) with respect to research and development of assistive technology and with the Institute for Future of Aging Service, an applied research unit of the American Association of Homes and Services for the Aging (AAHSA), concerning the long-term care workforce.

IAHSA is governed by a 15-member Board of Directors. Its staff consists of an Executive Director, Director of Professional Development, Program Administrator, as well as the President and CEO of AAHSA, in whose Washington, DC offices IAHSA's secretariat is located.

International Network for Prevention of Elder Abuse (INPEA)

INPEA, founded in 1997, in Adelaide, Australia at the 16th World Congress of the IAGG, has four main objectives:

1. to promote public awareness of abuse and neglect of older persons
2. to promote education and training of professionals and paraprofessionals in identification, treatment, and prevention
3. to engage in advocacy on behalf of abused and neglected elders
4. to stimulate research into the causes, consequences, prevalence, treatment, and prevention of elder abuse and neglect.

At the time it was established, representatives from 12 countries were recruited. Currently, INPEA has an organizational structure that includes an international slate of officers, six regional representatives (for Africa, Asia, Europe, Latin America, North America, and Oceania), 32 national representatives, four special advisors and, as is the case with most of the other international gerontology organizations listed here, a representative to the UN and to the Committee on Aging in New York. (The Committee on Ageing is a subcommittee of CONGO, the Committee of Nongovernmental Organizations in Consultative Status with the UN. Like the UN, it has branches in New York, Geneva, and Vienna.) In 2002, INPEA became a Standing Committee of the International Association of Gerontology and Geriatrics.

As part of its commitment to worldwide prevention of elder abuse, INPEA is dedicated to global information dissemination. Toward this end, INPEA produces a quarterly newsletter, available in both print and electronic formats. Research activities include a study, undertaken in partnership with the WHO Ageing and Life Course Programme, of older persons in community and primary health-care settings in eight countries (Argentina, Austria, Brazil, Canada, India, Kenya, Lebanon, and Sweden). The report, entitled *Missing Voices: Views of Older Persons on Elder Abuse*, was launched at the 2002 2nd World Assembly on Ageing in Madrid. Projects in progress include an environmental scan of information, resources, and services worldwide on issues of abuse of older adults. Called *World View on Elder Abuse and Neglect*, the goal of the project is to identify gaps and develop interventions and strategies to fill them. World Elder Abuse Awareness Day, which takes place on June 15, was initiated by INPEA in 2006.

International Longevity Centers (ILCs)

The ILCs are a network of independent, not-for-profit think tanks established to assist individuals and societies to address increased longevity and population aging in positive and productive ways and to highlight the contributions of older persons to their family and nation. The first two were established in 1990, in the United States and Japan. These were followed in chronological order of establishment by ILCs in the UK, France, the Dominican Republic,

India, and most recently (2005) Argentina. The centers work collaboratively and independently and each has a separate website describing its activities.

International Networks of Seniors Organizations

In addition to the organizations described previously, which are comprised of groups and individuals who work for seniors, there are a number of international networks of senior citizens organizations. These include the European Federation of Older Persons (EURAG), which was founded in 1962 and which has members in 32 European countries, and the International Federation of Senior Citizens Associations (FIAPA), which was established in 1971 as an international NGO linking seniors organizations in French-speaking countries in Africa, Asia, Europe, and the Indian Ocean. Additionally, there are organizations that serve as umbrella groups both for national and regional organizations of older persons and for organizations promoting the rights of older people. Examples include AGE, the European Older People's Platform. Established in 2001 to promote the interests of older people in the European Union, AGE is open both to EU national and regional organizations of older persons and organizations working for older persons. Readers should also see the website of the AARP for information on its Global Aging Program. While technically a national organization, AARP has had longstanding involvement in international gerontology. The same is true of Help the Aged, a UK charity that designates approximately 25% of its expenditures to overseas work, much of it in partnership with the HelpAge International network.

UN Aging-Related Activities and Agencies

1982 and 2002 World Assemblies on Ageing

The UN has convened two watershed gatherings concerned with aging and the aged. The first was a World Assembly that took place in 1982 in Vienna. The resulting *Vienna International Plan of Action on Ageing* (*Vienna Plan*) drew attention to the demographic changes that were occurring, at that time mainly in the developed world, and the need to recognize the elderly as a vulnerable population. The 2nd World Assembly on Ageing took place April 8–12, 2002 in Madrid, Spain. This assembly brought together delegations from the 192 member states of the UN to discuss and finalize an international strategic plan of action on aging for subsequent endorsement by the UN General Assembly and implementation by the UN member states. *The Madrid Political Declaration and International Plan of Action on Ageing* (*Madrid Plan*), like the *Vienna Plan*, is intended to provide a blueprint for governments in addressing the challenges of population aging. The document is comprehensive, containing 35 objectives and 239 recommendations for action, organized around three themes or priority directions:

1. Older persons and development
2. Advancing health and well-being into old age
3. Ensuring and enabling supportive environments.

The first priority direction draws attention to the fact that currently about two-thirds of all persons aged 60 and over live in developing countries and that by 2025 the proportion will increase to 75%. In doing so, it underscores the fact that while some are vulnerable, many are resources for development within the context of their family, community, and country. The second priority direction underscores the need for policies that promote good health in childhood and throughout the life course as a means of attaining a healthy old age. The third promotes policies and programs that will provide the basis for secure aging.

NGO World Forum on Ageing

Most of the delegates to the 2nd World Assembly on Ageing were elected and appointed government officials. Civil society was represented in a parallel event, held in Madrid on April 5–9, 2002. Nearly 1000 NGOs from five continents participated in the first NGO World Forum on Ageing. The main topics of discussion, summarized in the *Final Declaration and Recommendations of the World NGO Forum on Ageing*, centered on economic development and humanitarian aid rights of older persons, health care, housing, and consumption.

Valencia Forum

In the week prior to the 2nd World Assembly on Ageing (April 5–9, 2002), the IAGG brought together researchers, educators, and practitioners with expertise in gerontology and geriatrics in Valencia, Spain. The objective of the gathering, called the Valencia Forum, was to distill their knowledge and experience on how best to address issues associated with global aging, with particular emphasis on identifying information gaps and research priorities. These were articulated in the *Research Agenda on Ageing for the Twenty-First Century* (RAA-21), the product of a multiyear collaboration between the IAGG and the UN Programme on Ageing, which was endorsed by the Valencia Forum's participants. The research agenda was subsequently presented, together with a

report of the Valencia Forum, at an official roundtable at the World Assembly on Ageing held on April 9, 2002. The UN General Assembly in its 2002 resolution "Situation of Older Women in Society" welcomed the adoption of RAA-21 by the Valencia Forum. It was presented at the UN Economic Commission for Europe Ministerial Conference on Ageing, held September 11–13, 2002 in Berlin, Germany. Also, specific reference to RAA-21 was made at the UN Economic and Social Commission for Asia and the Pacific (ESCAP) Asia Pacific Follow-up to the 2nd World Assembly on Ageing held in Shanghai, China on September 23–26, 2002.

UN Programme on Ageing

The UN Programme on Ageing is located administratively within the Division of Social Policy and Development, Department of Economic and Social Affairs. Major responsibilities of the unit include ongoing coordination of UN activities in the area of aging, including promotion and monitoring of international policy and programs on aging; coordination of the International Year of Older Persons (1999), coordination of substantive preparations for the 2nd World Assembly on Ageing in Madrid (2000–2002), and post-Madrid, monitoring of implementation of the *Madrid International Plan of Action on Ageing*. The Programme on Ageing is also continuing its collaboration with the IAGG with respect to further development of the RAA-21 to reflect regional research priorities.

During 2003–2005, a series of workshops were held that focused on formulating regional research priorities, where possible in connection with the elaboration and adoption of regional strategies for the implementation of the *Madrid Plan*. The first of these was held in Cape Town, South Africa in association with the African regional conference GeriatrixAfrica '03 in March 2003. A report of this consultation was published in the July 2003 *IAG Newsletter*. Three subsequent regional consultations were convened, in the European, Latin American and the Caribbean, and Asia Pacific regions. The ESCAP and Economic Commission for Latin America and the Caribbean (ECLAC) regional implementation strategies for the *Madrid Plan* include specific recommendations for developing research agendas on aging at regional and country levels.

The programme's website contains all of the major documents from the two World Assemblies held to date, the NGO World Forum on Ageing, Valencia Forum, etc. An informal e-mail newsletter published by the unit, called the *UN Network on Ageing*, may also be found on the programme's website. The programme also maintains a very helpful searchable database on policies and programs on aging of UN member states.

WHO Life Course and Ageing Programme

The WHO Life Course and Ageing Programme is headquartered in Geneva within the Division of Non-communicable Diseases and Mental Health. Its mandate is to undertake projects and programs and develop publications aimed at improving the health and well-being of older persons. Recent examples include *Active Ageing: A Policy Framework,* developed as WHO's contribution to the 2nd World Assembly on Ageing, and *Towards Age-Friendly Primary Health Care*, a project developed in response to attention drawn in the *Madrid Plan* to the multiple barriers (physical, psychological, attitudinal, and financial) that older persons often encounter when attempting to access health services.

Recognizing that such barriers can have a large impact on older people's health, the latter project was aimed at determining what makes primary health-care services age friendly. Via focus groups conducted in five countries, the project documented the views of older people as well as those of health-care providers on whether primary health-care services are accessible, appropriate, and affordable for older persons; identified some of the most common barriers to primary health care for older adults in the areas of information, education, training, management, and the physical environment; and established a set of general principles for making primary health care more age friendly. Advocacy materials and a 'tool box' of materials on how to make primary health-care centers more age friendly are currently being compiled. A similar model is being followed in an international project concerned with making large and small cities more age friendly. This project, one of three major projects undertaken in partnership with the Public Health Agency of Canada, brings together researchers, community development experts, and seniors advocates from approximately 20 countries to address barriers to the full participation of older persons living in urban environments and ways these barriers may be overcome. Like the *Age-Friendly Primary Health Care* project, the goal is to develop a template or index and a tool kit that cities around the world can use to improve the quality of life of their older citizens. The other two projects sponsored by the Public Health Agency of Canada also merit special mention. One consists of an international falls prevention initiative, while the other focuses on disaster and emergency preparedness and planning. The costs in human suffering and

to health-care systems attributable to falls among seniors has been known for some time. Mortality data from Hurricane Katrina document another area in which the elderly are very much a vulnerable population.

Further examples that demonstrate the breadth of work undertaken by the WHO Life Course and Ageing Programme include a global survey on geriatrics in medical school curricula; a partnership with Health Canada and INPEA with respect to raising awareness of and prevention of elder abuse; the development of a global strategy on diet, physical activity, and health presented at the World Health Assembly in 2004; and the organization of a series of activities promoting physical activity in older age. The latter include the Global Movement for Active Ageing (a network of organizations and individuals from different disciplines that aims to influence policies and practices toward active aging); the Global Embrace (worldwide intergenerational walk events that take place annually around the UN International Day of Older People in October); and the Move for Health initiative (targeting all age groups and anchored on national models such as the Agita Brazil program).

International Institute on Ageing, UN–Malta (INIA)

Malta (in 1968) was the first country to draw the attention of the UN to aging as a matter of international concern. In 1979, the 35th General Assembly called on the Secretary-General to convene what was to become known as the 1st World Assembly on Ageing. In its resolution it recommended the promotion of training and research, as well as the exchange of information and knowledge, in order to provide an international basis for social policies and action. The *Vienna Plan* recommended the establishment of practical training institutes that would act as bridges between developed and developing countries. In 1987, the UN signed an agreement with the government of Malta to establish the International Institute on Ageing (INIA) as an autonomous body under the auspices of the UN and the host government. INIA is unique among the many gerontology centers that now exist around the world in having such an affiliation with the UN.

In accordance with its mandate, the institute's main objectives are to fulfill the training needs of developing countries. Since its establishment, INIA has trained approximately 2000 candidates from 133 countries in its programs held in Malta. Since 1995, it has hosted *in situ* training programs in 17 countries. The training programs are targeted for persons holding positions as policy makers, planners, program executives, educators, professionals, and paraprofessionals who work, or intend to work, in the field of aging or with older persons. The training programs are reinforced by INIA's other activities, which include data collection, documentation, information exchange, and technical cooperation, as well as research and publications.

INIA operates under the guidance of an International Board consisting of nine members. The Chair and six members are appointed by the Secretary-General of the UN, and two members are appointed by the government of Malta.

International Education Initiatives

In recent years, international training initiatives have expanded from short-term courses such as those offered by INIA to include cross-national postgraduate programs. These include the European Masters Programme in Gerontology, which is an interdisciplinary joint program, supported and delivered by 22 European universities, and the international continuing medical education certificate program offered by the European Academy for Medicine of Ageing. The latter, a 2-year modular training program, is designed to update knowledge, train teaching skills, and foster research in geriatric medicine as well as serve as a network for practicing geriatricians in Europe. New initiatives include a proposed Asia Pacific Academy for Health, Medicine and Ageing. The mission of the academy is to enhance the quality of professional education of its members and associate institutions in gerontology and geriatric medicine. Plans include fostering joint education, training, research, and service projects, disseminating scientific and health-care information, and stimulating intersectoral collaboration among governmental, non-governmental, and academic institutions. Inaugural members of the academy are the Novartis Foundation for Gerontology, the Centre for Ageing Studies (Adelaide, Australia), the Tsao Foundation (Singapore), the Hong Kong Institute of Gerontology, the Beijing Institute of Gerontology and Geriatrics, Population and Development Studies Center, and the Center on Ageing Studies (Renmin University of China, Asia Training Center on Ageing), and the International Association of Gerontology and Geriatrics, Asia/Oceania Region.

In addition, individual universities around the world are reaching out to international students, offering graduate education in gerontology and geriatrics online or in partnership arrangements, such as those of the University of New England, Australia and the Chinese University of Hong Kong, that combine online learning with *in situ* workshops, thereby

increasing accessibility for practicing professionals. Since 2001, the International Association of Gerontology and Geriatrics has maintained a worldwide listing of universities offering masters and doctoral degrees in gerontology on its website. Each succeeding year, the list has expanded.

Future Developments

The list of national gerontology and geriatrics societies has also expanded. With global aging, this trend is expected to continue. It reflects the development within countries of cadres of researchers, educators, and service providers specializing in gerontology and/or geriatrics who seek the company of others in the field to advance their personal knowledge, collectively impact local, regional, and national policies and programs, and to advocate on behalf of seniors. International gerontology offers opportunities to further expand their horizons and for cross-fertilization and collaboration across national borders and boundaries. Increasing numbers of individuals are taking advantage of these opportunities as evidenced both by the proliferation of international conferences, workshops, and symposia that have been organized over the past decade and by the increasingly large and geographically diverse attendance patterns they are showing. Around the world, individuals and governments are recognizing the value of international cooperation and collaboration with respect to research and education in gerontology and geriatrics as well as global sharing of best practices in services for seniors and their care providers, service delivery systems, and public policy.

See also: Careers in Aging; History of Gerontology; Organizations On Aging.

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Language and Communication in Aging

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Glossary

Aphasia – Loss of or impaired ability to speak, write, or understand language due to brain damage.

Dementia – Lasting deterioration of cognitive abilities resulting from any of a number of diseases affecting the brain.

Lexicon – Words or the vocabulary of a language as distinguished from its grammar and construction.

Syntax – The way in which linguistic elements (as words) are put together to form constituents (as phrases or clauses).

Introduction

It is commonly known that the loss of auditory and visual acuity leads to communication problems in many older adults. Some of these difficulties, such as problems reading small print or trouble hearing in noisy settings, can often be improved with corrective tools such as eyeglasses and hearing aids, or by environmental changes. Reports from older adults that common language tasks such as naming a particular object during conversation become more difficult in their 60s and 70s have been confirmed experimentally. In many cases, these difficulties cannot be fully explained by sensory deficits. This article reviews age-related changes in language as well as sensory, cognitive, and neurobiological factors that might underlie them. It also briefly considers the effects of interacting social factors, such as economic status, level of education, and gender, on language performance. The article concludes with a brief discussion of some pathological changes in language associated with neurological disorders.

Everyday Experiences of Older Adults

Whereas many language skills remain well-preserved in old age, older adults often perceive a decline in their communicative abilities. The most common language-related complaints include problems finding words in conversation, difficulty understanding spoken language under certain circumstances, and confronting ageism.

Finding Words

Diary studies, questionnaires, and anecdotal reports have demonstrated that older adults often experience difficulty finding the names of people, places, and objects. All speakers are familiar with the feeling that the word they want to use is 'on the tip of their tongue,' a phenomenon known as a tip-of-the-tongue (TOT) state. When older and younger adults are asked to keep a diary of their TOTs, older adults report significantly more TOTs than younger adults. Problematic words may include both low-frequency items and names of common objects. The words can often be successfully retrieved later.

Understanding Speech

Older adults often report difficulties understanding speech in less than ideal listening conditions: when the speech rate is fast, when there are competing stimuli (e.g., in a noisy room), or when they cannot see their conversation partner (e.g., on the phone). Whether this difficulty results from loss of hearing sensitivity, reduced central auditory processing ability, and/or cognitive decline is not well understood.

Ageism, Stereotypes, and 'Elderspeak'

Although some older adults (particularly those with neurological disorders) do have debilitating communication disorders, most healthy adults can

communicate effectively throughout their lives. However, in most industrial societies and Western cultures, older age is associated with some stereotypes and negative expectations, including false assumptions about communicative ability. For example, many people believe that, as a group, older adults are excessively talkative or poor at keeping a conversation on-target, a generalization that is not true for all older adults. It has also been shown that speakers often modulate their language, or use 'elderspeak' when addressing older adults, perhaps in an unconscious effort to compensate for a perceived hearing or comprehension deficit. This accommodation, which often comprises simplified structures, shorter utterances, a slower speech rate, and exaggerated intonation, may be useful to facilitate comprehension, but could also be perceived as patronizing, denoting a negative attitude and disrespect. Such ageist stereotypes have been reported in intergenerational communications, with both the younger interlocutors and the older adults themselves expecting the older speakers to have more communication difficulties.

Experimental Studies

Experimental studies suggest that some language abilities change with increasing age, while others vary little throughout the life span. In studies of language use, the following domains are often defined: phonological (relating to language sounds), lexical (word-level), semantic (relating to meaning), syntactic (phrase- or sentence-level), discourse (relating to groups of phrases or sentences), and pragmatic (relating to real-world or contextual knowledge). In reality, these domains are not easily separable. For example, the lexical skill of retrieving words requires the semantic knowledge of their meaning, and groups of sentences cannot be organized into meaningful discourse without an understanding of the listener's real-world expectations. Nevertheless, it is useful to discuss changes in adult language skills (in both production and comprehension) in the context of these domains. The findings reviewed in this section refer specifically to language abilities in healthy older adults, rather than in those impaired by brain injury or a neurological disorder. It is important to note that these changes are quite subtle. They become noticeable only in experimental settings and do not usually, create a daily communicative burden in older adults' lives.

Phonological Skills

It is commonly recognized that older adults' speech is qualitatively different from that of younger adults. It has been shown that listeners can reliably distinguish between older and younger adults, although they might not be able to describe the differences. Older adults' speech is usually lower in volume, slower, and somewhat less precise in articulation (the movements of the mouth and tongue that produce speech) than that of younger adults. Older adults' speech can also be less fluent, including more pauses, fillers, repetitions, and corrections. However, in the absence of overt damage or disease processes, speech skills in older adults remain sufficiently high for everyday communication.

Research studies have suggested that older adults have more difficulty in processing speech input than younger adults. Although hearing loss has been highly correlated with speech-processing difficulty, it has been documented that older listeners have particular difficulty with several forms of distorted speech, including noisy, reverberant, and time-compressed speech, beyond what the loss of hearing sensitivity might predict.

Lexical Skills

Word-level production in older adults has been particularly well studied, in part because lexical retrieval, the spontaneous production of a specific word, is anecdotally reported to decline with increasing age. In list generation tasks, in which participants are asked to name as many items as possible from a single category (e.g., animals) in a fixed amount of time (usually 1 min), older adults produce fewer words than younger adults. Studies have also confirmed that older adults are slower and make more errors than younger adults in naming objects depicted in pictures. Difficulty has been documented for adults as young as in their 50s, but significant age differences are usually found only for individuals who are 70 years and older, as seen in **Figure 1**.

Because the retrieval difficulty is often overcome with the assistance of semantic or phonemic cues, it seems clear that knowledge of the words is intact, even when their phonological form is inaccessible. Indeed, vocabulary knowledge shows little evidence of decline with increasing age. Although some studies have suggested that the quality of definitions given by older adults is poorer than that of younger ones, the preponderance of the evidence suggests that adults maintain their knowledge of word meanings and can continue to build their vocabularies well into their later years.

Semantic Skills

There is good reason to believe that semantic abilities remain largely intact throughout adulthood. As noted previously, word retrieval studies show that,

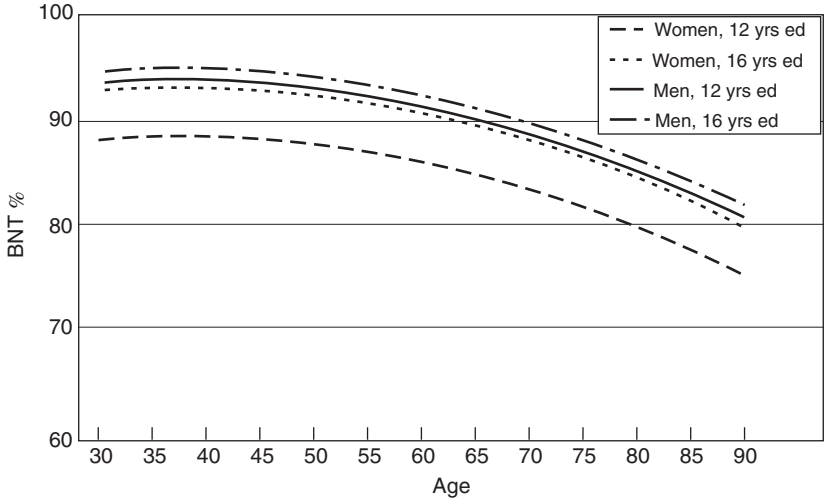

Figure 1 Predicted performance (% correct) on the Boston Naming Test by age, gender, and education. Reprinted from Connor LT, Spiro A, Obler LK, and Albert ML. *Journal of Gerontology: Psychological Sciences* 59B(5): P203–P209 (2004). Copyright © The Gerontological Society of America. Reproduced by permission of the publisher.

even when older adults report difficulties in finding a word, they are still able to produce the word when cued, suggesting that they retain their underlying knowledge of its meaning. Older adults' generally good performance on vocabulary tests also indicates intact semantic knowledge. Furthermore, in lexical decision tasks, semantic priming (the phenomenon of recognizing a word more quickly when it is preceded by a semantically related word) appears to be equally robust in older and younger adults. Likewise, studies of sentence comprehension have confirmed that older adults' capacity to comprehend words in sentences appears intact, unless the sentences are complex or posit counterintuitive statements.

Syntactic Skills

Syntactic production skills are those with which a speaker or writer organizes words into grammatically acceptable phrases and sentences. Sentences may be syntactically simple (containing only one clause) or more complex (with one or more dependent clauses). In spontaneous speech and in diaries, older adults show evidence of declining syntactic abilities, as they tend to use simpler syntactic structures and make more errors than younger adults.

Moreover, there is evidence that the comprehension of sentences becomes more difficult with increasing age. Older adults are slower and less accurate than younger adults in paraphrasing, answering questions about, and making judgments about syntactically complex sentences. These changes have been reported in both reading and listening skills. The sentences that cause older adults difficulty are typically unusually long, somewhat counterintuitive, syntactically complex, or not fully comprehensible by context alone. For example, the sentence 'The patient who examined the physician completed the forms' is difficult syntactically and pragmatically – syntactically because a dependent clause, 'who examined the physician,' is embedded in the main clause 'the patient completed the forms,' and pragmatically because patients do not usually examine physicians. These types of complexities often force listeners to use their working memory to repeat sentences to themselves as they listen. It is not yet clear whether syntactic knowledge itself or the ability to use that knowledge efficiently is impaired in older adults who find these sentences difficult to process.

Studies of resource allocation during language processing also suggest that older and younger adults show differences in processing complex sentences. Younger, but not older, adults have been shown to allocate longer reading times to more complex syntactic structures (e.g., object-relative sentences) than to less complex ones (e.g., subject-relative sentences), as seen in **Figure 2**.

Discourse Skills

Studies of discourse in older adults have examined naturalistic (e.g., spontaneous conversations, letters) and elicited production (storytelling, picture descriptions) and found some evidence of differences between the discourse of older and younger adults. However, individual differences in discourse performance are great among adults of all ages, making it difficult to generalize across age groups. More than in other language domains, personal style contributes to

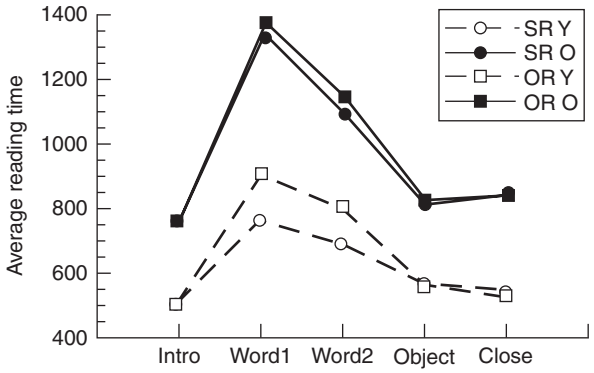

Figure 2 Average reading times (milliseconds) for complex sentences by age and syntactic structure (Y, younger adults, ages 19–27; O, older adults, ages 59–80; SR, subject-relative sentences; OR, object-relative sentences). Copyright 2000 from 'Age differences in on-line syntactic processing,' *Experimental Aging Research* 26: 315–322 by Stine-Morrow EAL, Ryan S, and Leonard JS. Reproduced by permission of Taylor and Francis Group, LLC, http://www.taylorandfrancis.com.

discourse performance. (Quite simply, some people love to talk, while others are more reserved; whereas some elaborate, others speak tersely.)

The belief that older adults tend toward greater verbosity has been verified in some studies. In these cases, the talkativeness seems to have been partly motivated by social needs unrelated to age; the more talkative older adults tended to be more outgoing and less concerned with others' opinions of them. This loquacity might also be prompted by lexical retrieval or memory problems, as people circumlocute (describe a word or its characteristics instead of speaking the word itself) around their targets. The additional possibility that some of these verbose adults are in the early stages of dementing disorders cannot be excluded.

The use of referring expressions (e.g., pronouns) has also been reported to differ in older and younger populations. To use these expressions clearly, speakers must mark the antecedent (the word for which the pronoun stands) unambiguously. Older adults tend to be less specific in their use of referring expressions. As with other differences, it is not clear whether these ambiguities are related to cognitive deficits such as memory and attention, problems comprehending the topic, or pragmatic difficulties in recognizing the listener's perspective.

Older adults are often less skilled in retelling stories or giving instructions for completing a task, as they omit more essential elements than younger adults, creating discourse that is less fluent and harder to follow. However, the quality of discourse is not easily quantified. Some evidence suggests that, using more subjective measures of discourse ability (e.g., clarity, interest to the listener), older adult discourse appears superior. Older adults have shown some evidence of poorer comprehension and organization of discourse in story recognition or recall tasks, with more difficulties drawing inferences and logical conclusions, organizing the story elements, and remembering the stories after a delay.

Pragmatic and Non-verbal Skills

Few systematic examinations of older adults' abilities to use pragmatic skills have been undertaken. However, in examinations of other linguistic abilities, real-world expectations are often manipulated. As noted in the discussion of syntactic skills, older adults tend to have an especially difficult time processing complex sentences when they are counter to real-world expectations. For older adults with impaired hearing, access to non-verbal cues is especially important. Some researchers have reported that older adults are poorer than younger adults at identifying an emotion encoded in a facial expression without the aid of auditory cues.

Factors Contributing to Language Change

Sensory, cognitive, and neurobiological changes have all been shown to explain some of the language differences between older and younger adults. Sensory deficits that clearly contribute to language deficits include loss of visual and aural acuity. Non-linguistic cognitive abilities such as cognitive speed, working memory, executive function, and possibly attentional inhibition have been shown to decline with increasing age and have been hypothesized to mediate some age-related language changes. This section gives an overview of the sensory, cognitive, and neurobiological changes that have been implicated in language performance. Changes in the brain and sensory organs are often thought to cause cognitive changes that, in turn, result in changes in language performance. However, it has also been hypothesized that a common factor leads to sensory, cognitive, and language deficits. This view, termed 'the common cause hypothesis,' posits that decline in sensory abilities is not the cause of cognitive decline, but rather a marker of the same physiological changes that lead to cognitive deficits.

Sensory Changes

Sensory changes in the visual and auditory modalities accompany the process of healthy aging. These changes have implications for successful communication in older age.

Vision changes associated with aging may include peripheral problems such as presbyopia, miosis,

cataract, and posterior vitreous detachment, as well as disorders like glaucoma, macular degeneration, and diabetic retinopathy (*see* Vision). These disorders may cause a range of symptoms, from difficulty focusing on nearby objects and diminished night vision to blindness. Decreased visual acuity has both direct and indirect effects on communication. Visual input is integral to typical conversation. Nonverbal cues supplement verbal communication, and their absence or lessening makes conversation more difficult. Furthermore, reading and writing skills may be compromised. Indirectly, loss of vision affects social interaction in older age. The ability to view movies and television is reduced, and driving skills may be compromised, which may lead to reduced social activity and increased isolation. Decreased ability to read instructions on medication packages or any number of forms may be harmful as well.

Hearing impairment associated with older age (presbycusis) includes changes in the ear, the auditory nerve, and the auditory pathways (*see* Hearing). These changes are associated with loss of sensitivity, especially for high-frequency sounds, and often with poor sound discrimination and impaired speech recognition.

On pure tone testing, age-related changes are typically characterized by a high-frequency loss that becomes progressively more severe with advancing age. Whereas not all age-related hearing changes directly affect speech recognition skills, a decline in speech recognition often corresponds to pure tone loss. However, the relation between older adults' ability to understand speech, particularly in noisy conditions, and their peripheral hearing loss has been a matter of debate.

One approach, the peripheral hypothesis, maintains that difficulty understanding speech can be accounted for by hearing loss as measured by pure tone. Several studies have demonstrated that older adults with unimpaired hearing perform as well as younger adults, whereas younger adults with hearing impairment perform similarly to older adults with hearing impairment. In contrast, other studies demonstrated that older adults with normal hearing performed less well than younger adults on measures of speech recognition in noise, which suggests that older adults may experience difficulty with speech perception (at least in noisy conditions) beyond their threshold sensitivity. These latter findings lead to the hypothesis of a central auditory processing deficit.

Whether the deficit is predominantly peripheral or central, hearing changes are very common in individuals 65 and over, and their impact is often underestimated. Older adults who suffer uncorrected hearing impairment tend to minimize their social interaction and self-rate their psychosocial, emotional, and recreational impairment as greater than older adults with no hearing loss.

Despite the wide availability of hearing aids, including some very sensitive and advanced instruments, the majority of older adults with hearing loss do not use hearing aids. According to surveys, perhaps 20% of the hearing-impaired older population use hearing aids. Reasons for this low proportion of users may include reluctance to admit to hearing loss, which is associated with being old and/or disabled, low tolerance for a noisy environment often exaggerated by the hearing aids, difficulty handling the small devices, and affordability. Appropriate fitting is crucial, and should be made on the basis of physical (e.g., type of hearing loss, structure of the ear), psychosocial (e.g., motivation, lifestyle), and financial criteria. Also important is the postfitting process, during which the aids are evaluated and adjusted. Studies of self-report on use and satisfaction (most commonly used is the 25-item Hearing Handicap Inventory for the Elderly [HHIE]) demonstrate that those who are fitted properly can derive dramatic benefit from hearing aids.

Non-linguistic Cognitive Changes

Leading theories of language performance in aging propose that an age-related decline in language is mediated by changes in cognitive skills, such as processing speed, working memory, executive function, and attention. Such skills are relevant to performance on language tasks that are harder for older adults, and there is evidence that all of them decline with increasing age.

Slower cognitive processing has been theorized to mediate age-related cognitive decline. Older adults usually take longer than younger adults to complete most cognitive tasks. Slower performance has been demonstrated even when the speed it takes to perform the motor aspects of the tests has been accounted for. Slowed processing could affect a number of the language tasks in which speed is measured or time is restricted, including list generation, picture naming, and auditory comprehension. Although cognitive speed has been related to performance on these tests, it is not sufficient to explain older adults' difficulties with such tasks.

Working memory skills, the ability to simultaneously remember and manipulate information, are also known to decline with increasing age. Older adults experience difficulty on tasks that require them to remember numbers, words, or shapes while performing a second task such as reading sentences

or computing numbers. In the verbal domain, good working memory skills are useful in auditory sentence comprehension, as the listener determines who is doing what to whom, especially when sentences are long and complex. Indeed, compromised working memory skills have been proposed to underlie older adults' difficulty in processing syntactically complex sentences and recalling information from written or auditory discourse, as mentioned above.

Executive function refers to the set of cognitive skills, such as identifying options, setting goals, initiating behavior, and tracking performance, that allow a person to successfully plan and execute a task. Older adults often demonstrate impaired performance on tasks that measure these abilities. It has been proposed that executive dysfunction accounts for certain impairments in language skills. For example, list generation tasks utilize executive function skills such as switching between semantic subcategories (e.g., farm animals and house pets).

Attentional inhibition refers to the ability to attend to relevant stimuli while ignoring irrelevant information. Although no consensus exists as to whether older adults do in fact exhibit deficits in attentional inhibition, difficulty inhibiting non-target words could contribute to lexical retrieval errors, resulting in the generation of a related but incorrect word (e.g., 'chair' instead of 'stool'). Moreover, in comprehension tests, an inability to ignore noise or irrelevant information may hinder understanding of the target material. For listeners presented with long auditory or written passages, difficulty attending to the relevant information while ignoring extraneous details could impair the ability to report the gist of the discourse or answer questions about it.

Neurobiological Changes: Anatomical, Chemical, and Physiological

The adult brain may exhibit many changes as it ages, including a reduction in volume, alterations in activation patterns, and differences in neurotransmitter circuits. Shrinkage of the brain may be related to changes in the white matter, the myelinated axons that carry neuronal signals. Structural imaging studies have shown that white matter volume decreases and that white matter hyperintensities increase; both these phenomena have been associated with worse performance on tests of executive function, processing speed, and explicit memory. Functional imaging studies reveal that some older adults show bilateral activation of the dorsolateral prefrontal cortex (rather than the typical left hemisphere activation seen in younger adults) when performing verbal working memory tasks. This bilateral activation could be either a compensatory mechanism or the result of an inability to suppress activation. Changes in the neurotransmitter dopamine also occur in the older adult brain, as dopamine concentration and receptor density decline with increasing age. Dopamine has been associated with psychomotor speed tests and cognitive functions.

Explaining Individual Differences

While older adults as a group show the patterns of language change discussed above, the performance of individual adults varies considerably, with some people showing a measurable decline in their 70s and 80s and others performing quite well throughout their lives. What accounts for this within-group variability is an important question for both experimental studies and clinical assessments.

A number of social variables, including the education, socioeconomic status, and gender of the participant, have been reported to contribute to individual performance differences on language tests. For example, a person with an advanced degree is likely to have more experience in defining the obscure words found on a vocabulary test than a high school graduate. Indeed, research studies on the relation between language and cognition have reported that on such measures, individuals with higher education outperform individuals with lower education.

Other aspects of performance variation are more personal, such as motivation, interest, cognitive style, and depression status. Understandably, individuals do better on tasks that tap their own interests and strengths and those that they find relevant to their own lives. With respect to motivation, low expectations by either the participant or the examiner have been related to poorer performance. Lack of motivation may be a manifestation of fatigue or illness, which also may contribute to poor performance.

Certain aspects of the assessment setting have also been shown to influence individuals' performance differently. Adequate lighting, readable print, and minimal noise are essential for maximizing the performance of hearing- or vision-impaired participants. For tasks that are unfamiliar, adequate practice opportunities before assessment begins have been shown to help older adults more than younger adults. An institutional effect has also been observed, as community-dwelling individuals tend to perform better than those who reside in nursing homes.

In most language and cognitive domains, there are little data on the performance of older individuals who are bilingual and bicultural. Indeed, since the 1990s, clinicians and researchers have begun to

emphasize the need to establish norms for bilingual participants on commonly used neuropsychological and language tests. Testing bilinguals in both their languages demonstrates that proficiency in each language affects levels of performance. In addition, the mean scores obtained for bilingual participants differ from those of monolingual individuals. For example, bilingual speakers may name fewer pictures correctly and generate fewer words on list generation tasks in each of their languages than expected on the basis of monolingual norms. Lower scores of bilinguals on normative tests developed in English, as well as tests translated into other languages, may be due in part to language-specific differences. Variations in word length, semantic relations, and level of proficiency may interact with test materials as they are translated or adapted from one language to another. Not only language considerations but also cultural differences should be addressed when bilingual individuals are concerned. Cultural differences can account for different approaches to problem solving and dealing with task demands, as well as for varying strategic flexibility. Furthermore, attitudes toward older individuals vary across different cultures, affecting communication between younger and older adults.

Language and Communication Disorders

Brain injury or neurodegenerative disease often produces serious language disorders in adults. This section gives an overview of the language problems that result from two types of neurological disorders to which older adults are disproportionately subject: cerebrovascular accident (commonly called stroke), which may lead to aphasia, and dementia of the Alzheimer type. It also briefly considers the implications of aging for adults with childhood language disorders.

Aphasia

Aphasia (*see* Language Disorders: Aphasia) is an acquired language disorder resulting from injury to the brain, usually a stroke in the left hemisphere. The spontaneous speech of a person with aphasia is almost always somewhat impaired, and other language abilities such as reading, writing, repetition, and comprehension may also show deficits. Aphasic disorders may be broadly categorized as fluent or non-fluent. The non-fluent aphasias include global aphasia, Broca's aphasia, and transcortical motor aphasia. Among the fluent aphasias are Wernicke's aphasia, transcortical sensory aphasia, conduction aphasia, and anomic aphasia. Patients with fluent aphasias tend, on average, to be about a decade older than patients with non-fluent aphasias.

Language in Dementia of the Alzheimer Type

The language changes that accompany dementing disorders are most pervasive in dementia of the Alzheimer type (DAT) (*see* Dementia; Dementia: Alzheimer's). Although language skills, like other cognitive abilities in people with DAT, follow a progressively declining course, a number of linguistic domains remain relatively intact in both the early and middle stages of the disease. Because the motor speech skills (such as articulation, resonance, and phonation) that produce language sounds are largely intact, words are generally intelligible, even when their meaning becomes distorted. Output follows the phonological rules of the language. For example, speakers do not substitute sounds characteristic of their language for those found in another language, or produce sound combinations not found in their language. People with DAT also tend to follow the syntactic conventions of their language. For example, they do not usually violate the morphosyntactic rules by which affixes are added to words to mark their use in a sentence. Prosody (the distinctive rhythm of speech, which rises and falls in predictable ways) is also normal in speakers with DAT.

Despite these preserved skills, the language of people with early-stage DAT is characterized by impairments in lexical retrieval and discourse competence. Speakers with DAT often show great difficulty in retrieving words, substituting either a semantic or phonemic paraphasia (word production error) for the target word, or using a vague filler such as 'thing' in place of a more meaningful word. The coherence of the speech is further hampered by tendencies to wander from the conversation topic and to repeat words or phrases. Since the speaker's prosody and grammar are normal, the word-finding difficulties may complicate, but do not preclude, conversation in the early stages of the disease. As to comprehension, complex discourse will present a challenge.

In the middle stages of DAT, language difficulties substantially impair communication. Lexical retrieval problems become more severe, giving way to large gaps in conversation and circumlocutions, descriptions of a target word or its functions that are spoken in place of the word itself. Speakers also begin to show a variety of difficulties with discourse-level language. The early-stage tendency to lose the topic of the conversation becomes more pronounced, such that the discourse becomes virtually incoherent. The speaker often appears unaware of the listener's knowledge of or interest in the topic. Bilinguals with

DAT may use a language with a conversation partner who does not know the language; before their dementia they would have avoided doing this.

By the late stages of DAT, speech is virtually incomprehensible, and in the most severe cases, speech ceases completely. Comprehension is also severely impaired, such that patients are unable to engage in meaningful communication.

Developmental Language Disorders

An area that has not been well studied is the language performance in adulthood of people with developmental language disorders (e.g., stuttering, dyslexia). Diagnosis and treatment of childhood language problems were much less available when contemporary older adults were children, and many people who would now be recognized as having disordered language were not identified as such in childhood. This makes a systematic study of age-related changes in individuals with developmental language disorders difficult, but a consideration of this subgroup of older adults is important to developing a fuller understanding of language changes in aging.

Summary

Most healthy adults communicate successfully throughout their lives, but experimental studies have illuminated subtle differences in performance on language tasks after middle age. Some of these changes, such as poorer speech processing and less accurate are undoubtedly related to the loss of auditory acuity. Studies have also shown that older adults have more difficulty finding specific words, and making inferences from complicated discourse. On the other hand, the semantic knowledge of words and the understanding of real-world expectations, as well as certain storytelling skills, appear to remain unimpaired.

Diminishing cognitive skills such as cognitive speed, working memory, executive function, and attention have been suggested as mediators of declining language skills. Overall health and its related factors of fatigue and motor speed also contribute to performance, especially in time-limited assessments. Individual performance is further influenced by social variables such as level of education, gender, culture, and socioeconomic status, and by behavioral factors such as motivation, interest, and the comfort of the assessment environment.

See also: Dementia; Dementia: Alzheimer's; Hearing; Language Disorders: Aphasia; Language Disorders: General; Vision.

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Language Disorders: Aphasia

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Glossary

Agrammatism – Characterized by articles, auxiliary verbs and some prepositions omitted or unrecognized in speech and writing.

Agraphia – Characterized by an inability to produce written language.

Alexia – Characterized by an impaired ability to recognize words and/or letters, thus affecting the ability to extract meaning from written text.

Anomia – Characterized by a struggle to find appropriate words in naming items and conversational speech.

Anomic Aphasia (also known as amnestic aphasia, nominal aphasia, and semantic aphasia) – Characterized by a failure to name or to retrieve names, and common and proper nouns in speech.

Apraxia (also called aphemia) – Characterized by errors in the selection or ordering of sounds such that resulting erroneous words sound like the target word but have the wrong meaning or are so distorted as to be non-words.

Broca's Aphasia (also known as verbal aphasia, expressive aphasia, and motor aphasia) – Characterized by speech output exhibiting poorly articulated words with missing, added, or transposed sounds, difficulty initiating speech, and reduced vocabulary.

Conduction Aphasia (also called central aphasia, repetition aphasia, and afferent motor aphasia) – Characterized by the repetition of individual sounds or words in speech.

Global Aphasia (also called total aphasia) – Characterized by equal impairment of all language modalities.

Wernicke's Aphasia (also called syntactic aphasia, sensory aphasia, and receptive aphasia) – Characterized by impairment in the understanding of spoken language.

Introduction

Kertesz (1979: p. 2) defined aphasia as "a neurologically central disturbance of language characterized by paraphasias, word finding difficulty, and variably impaired comprehension, associated with disturbance of reading and writing, at times with dysarthria, non-verbal constructional, and problem-solving difficulty and impairment of gesture." Goodglass and Kaplan (1983: p. 5) defined aphasia as "the disturbance of any or all of the skills, associations and habits of spoken or written language produced by injury to certain brain areas that are specialized for these functions." Basso and Cubelli (1999: p. 181) defined aphasia as "a disorder of verbal communication due to an acquired lesion of the central nervous system, involving one or more aspects of the processes of comprehending and producing verbal messages." Implicit in these definitions, of course, is a definition of language, itself a relatively complex concept.

The clinical syndromes of aphasia have been associated with particular anatomical loci in the central nervous system in the literature since the nineteenth century. Contemporary research, particularly aided with the used of modern brain-imaging techniques, suggests that in addition to the so-called classical language areas of the dominant (usually, left) hemisphere's cortex (Broca's area, Wernicke's area, etc.), many other areas of the central nervous system participate in language processing, including subcortical structures (including the basal ganglia, cerebellum and thalamus), other cortical areas of the dominant hemisphere (including inferior and mesial temporal lobe and insula) as well as various regions of the non-dominant hemisphere. This article focuses on aphasia as a behavior and not its anatomical substrate.

Approaches

In broad outline, there are two approaches to understanding the nature of aphasia. The first is concerned with functional components, what people do when engaged in language behaviors; the four modalities of language – speaking, listening, reading, and writing – are examples of functional components. Other functional components of language include being able to repeat what is said, initiating speech, speaking fluently, being able to name things and people, and being able to clearly articulate words. This approach to aphasia has typically been clinical; identifying impaired functional components of language in conjunction with impairments in one or more of the four modalities has led to a clinical classification of the aphasias that is used in assessment, rehabilitation, and research. An active area of

research in this approach has been correlating the loci of brain lesions with functionally identified syndromes of aphasia.

The second approach might be termed neurolinguistic; it is concerned with the structure of language and which linguistic structures are impaired in aphasia. This approach begins with analyses of aphasic language in terms of linguistic levels – phonological, morphological, syntactic, semantic, and discourse – and then may take either an experimental or applied tack, correlating linguistic deficits, brain lesions, and clinical syndromes. The neurolinguistic approach typically furnishes linguistic details to the functional-clinical approach, particularly in research applications.

Studying the localization of lesions that cause aphasia was at one time of major clinical importance; modern imaging techniques, applied to both brain-damaged aphasic patients and non-brain-damaged experimental subjects, have shifted emphasis to questions of which parts of the brain subserve which language functions and/or which language structures. A reasonable goal would be to identify a unique brain structure and its connections, damage to which caused a well-defined clinical aphasia syndrome and a well-defined linguistic impairment.

Functional-Clinical Aphasia Syndromes

Broca's Aphasia

Broca's aphasia has also been called verbal aphasia, expressive aphasia, efferent motor aphasia, and motor aphasia. The primary modality of language that is affected is speech production, but writing is often affected, too. Comprehension of spoken language and reading are usually much better preserved. According to the older scheme of dividing the aphasias into fluent and non-fluent, Broca's aphasia is the common variant of non-fluent aphasia. Speech output tends to exhibit poorly articulated words with missing, added, or transposed sounds, and there is usually difficulty in initiating speech. The range of vocabulary is often reduced from premorbid levels, and speech output tends to rely a great deal on basic, highly familiar, and thus overlearned speech patterns. Speech is likely to be in short phrases with fewer words than expected, punctuated with frequent pauses. Commonly seen in Broca's aphasia is agrammatism, speech and writing in which the small elements of grammatical structure, typically the so-called function words such as articles, auxiliary verbs, and some prepositions, are omitted or unrecognized. Anomia is also fairly common, causing patients to struggle with finding the appropriate word, both in conversational speech and in confrontational naming. Although comprehension is noticeably better than production, some patients with Broca's aphasia have difficulty comprehending less frequent syntactic structures, although most demonstrate the ability to comprehend single nouns, verbs, or adjectives. Errors may occur in word order, which is called paragrammatism, but this is more common to Wernicke's aphasia (discussed next). Nouns tend to be preserved better than verbs and adjectives in Broca's aphasia, but grammatical function words are the most impaired. A concomitant of the shorter phrases and frequent pauses seen in Broca's aphasia is an impairment in prosody, alterations such as impaired inflection, pitch, and rhythm; this is commonly referred to as dysprosody. Repetition often shows the same impairments as in conversational speech. Writing in Broca's aphasia tends to be impaired analogously to speech output, but reading ability may be only mildly impaired; writing will exhibit misspellings, letter omissions, poor formation of letters, and agrammatism. Patients with Broca's aphasia are generally more aware that their speech and language is impaired than those with Wernicke's aphasia and thus may struggle to produce more correct responses.

The lesions typically leading to Broca's aphasia most often affect both the inferior frontal lobe and the anterior inferior portion of the parietal lobe; this is generally more extensive than the part of the third (inferior) frontal gyrus and surrounds that have been identified as Broca's area.

Wernicke's Aphasia

Wernicke's aphasia has also been called syntactic aphasia, acoustic aphasia, sensory aphasia, and receptive aphasia. The primary modality of language that is affected is speech perception, and reading may be affected, too. The ability to produce speech and the ability to write are usually much better preserved, although the content of speech and writing will likely be impaired. According to the older scheme of dividing the aphasias into fluent and non-fluent, Wernicke's aphasia is the common variant of fluent aphasia. The salient feature of Wernicke's aphasia is an impairment in understanding spoken language, particularly when the content of the spoken language is not predictable from the context or not otherwise highly familiar. In milder forms, comprehension may be contextually appropriate, e.g., a discussion of the weather, but lacking in details, e.g., unable to distinguish partially cloudy from overcast. On the other hand, the speech of the Wernicke's aphasic patient may appear articulatorily fluent but paraphasic, that is, an intrusion of non-words, words out of order, and word choices that are marginally related or unrelated

to the topic of the conversation. Paraphasias may appear in any variety of aphasia, but they are typically more prevalent in Wernicke's aphasia. As in Broca's aphasia, grammar may be affected, rather than function words being omitted, they are more likely to be used improperly or added extraneously. Grammatical word order constraints may be violated, a syntactic impairment called paragrammatism. Wernicke's aphasic patients are not likely to use complex sentence structure but rather will resort to simple, common declarative word order. Occasionally, patients with Wernicke's aphasia may talk excessively, even to the point of adding unrecognizable syllables, words, or phrases to their speech, a phenomenon known as jargon aphasia. Most researchers consider jargon aphasia to be a subtype of Wernicke's aphasia. In jargon aphasia, the jargon aphasic errors may be literal (single sounds), verbal (added words that are recognizable), or neologistic (added words that are unrecognizable). The patient with Wernicke's aphasia may be able to write letters and words correctly as a motor action, but the output reflects the patient's fluent paraphasic speech, including a disorganized and rambling style, occasional to frequent repetitions of words or phrases, jargon aphasic errors, and a lack of recognizable content. Reading tends to follow auditory comprehension ability, typically impaired.

The lesions responsible for Wernicke's aphasia are typically in the middle to posterior temporal lobe, particularly the superior gyrus, but frequently the middle temporal gyrus as well. These lesions often continue back to the junctions of the temporal lobe with the occipital and inferior parietal lobes, in the areas named the supramarginal and angular gyri.

Conduction Aphasia

Conduction aphasia has also been called central aphasia, disorganized execution of the encoding program related to disturbed auditory feedback, repetition aphasia, and afferent motor aphasia. The primary function of language that is affected is the repetition of speech, whereas comprehension and production tend to be much less impaired. Conduction aphasic patients frequently attempt to correct their repetition errors, implying a better preserved comprehension. The repetition errors may be at the level of individual sounds or words; repetition may exhibit an agrammatic character. The speech of the patient with conduction aphasia is more often like that seen in Wernicke's aphasia but sometimes is like that seen in Broca's aphasia. In addition to the repetition deficit, patients with conduction aphasia are often afflicted with anomia; literal paraphasias (substitution of sounds) may intrude in both spontaneous speaking and in attempts to repeat what is heard. Within single words or very short phrases, articulatory fluency may be good, but patients with conduction aphasia typically display phonemic (or literal) paraphasias, a substitution of sounds. Although within-phrase syntactic patterns tend to be normal, many conduction aphasic patients have difficulty with sentences containing pronouns and grammatical function words, as well as polysyllabic words. Other characteristics that may be found include difficulties in writing, showing some forms of agraphia and ideomotor apraxia. Writing ability usually parallels speech output, showing deficits in spelling and letter omissions or substitutions. As is the case for Broca's aphasia, conduction aphasic patients are typically aware of their speech and language deficits.

The lesions leading to conduction aphasia tend to be located in and around the supramarginal gyrus and the arcuate fasciculus; the latter pathway connects the temporal lobe to the frontal lobe. Other lesions are along the border of the Sylvian fissure, extending to the subjacent white matter.

Anomic Aphasia

Anomic aphasia is also known as amnestic or amnesic aphasia, nominal aphasia, and semantic aphasia. The primary modality of language that is affected is speech production, restricted to the production of names, but it is most easily observed by asking an aphasic patient to name an object, so an input problem cannot be excluded. Anomia is described by the failure to name or to retrieve names, common and proper nouns; auditory comprehension is either unimpaired or only mildly impaired. One manifestation of anomic speech is a fluent output that lacks the nouns and verbs related to concepts. As a result, speech may be described as empty. Speech rate, articulation, and, surprisingly, grammar are typically normal, and the on-line deficits in word retrieval may be signaled by noticeable pauses. Accompanying impaired naming is the inability to comprehend nouns or verbs in isolation; however, object recognition is usually quite good. Although reading and writing are usually preserved, in severe cases of anomia there may be an anomic alexia or anomic agraphia. Some degree of anomia is found in virtually all varieties of aphasia; in part for that reason, no specific localization for the causative lesions has been or is likely to be documented.

Global Aphasia

Global aphasia has also been called total aphasia. All language modalities are affected in global aphasia to an equal degree, unlike the other aphasias, in which a

processing disparity among the modalities is evident. The causative lesions leading to global aphasia are typically very large, subtending all or most of language cortex.

Single-Modality Functional-Clinical Aphasia Syndromes

There are a number of aphasia syndromes that predominantly affect a single language modality.

Apraxia of Speech

Apraxia of speech has also been called aphemia, verbal apraxia, articulatory apraxia, and anarthria. Not all researchers agree that this is an aphasia syndrome; it is included here because, by definition, motor control of the speech musculature is not affected in apraxia of speech, in other words, it is independent of dysarthria. Apraxia of speech often accompanies Broca's aphasia but may be an independent, modality-specific impairment. The modality affected is speaking, and the problems are best described as errors in the selection or ordering of sounds such that the resultant erroneous words either sound something like the target word but have the wrong meaning or are so distorted that they are no longer words of the language.

Alexia with Agraphia

Alexia and agraphia are, respectively, input and output impairments of written language. Alexia and agraphia may occur independently or together; alexia with agraphia has also been called parietal-temporal alexia, central alexia, semantic alexia, angular alexia, and letter blindness. The primary modalities of language that are affected are reading and writing. Patients suffering from alexia with agraphia display impairments in both reading and writing skills. In general, their ability to copy words tends to be better preserved than their spontaneous writing ability. The inability to read and write extends into domains other than visual language: numbers, musical notation, and chemical formulas can also be impaired. Speech output and auditory comprehension may be somewhat impaired but typically only in a mild form of anomia. Both the location and the size of the lesion will strongly influence the manifestation of any aphasia, but these are particularly relevant in the impairment described as alexia with agraphia; the causative lesions are predominantly found in the region of the angular gyrus.

Pure Word Deafness

Pure word deafness has also been called auditory agnosia, isolated speech deafness, and subcortical sensory aphasia; the modality affected is hearing. It causes patients to be unable to recognize speech sounds, while being able to hear non-language environmental noises, animal sounds, and music. Other language modalities – speech production, reading, and writing – generally remain intact. Lesions typically leave Wernicke's area undamaged, but destroy both Heschl's gyrus (primary auditory cortex) in the language hemisphere and the afferent auditory pathways coming from the non-language hemisphere. The functional result is that Wernicke's area behaves as though it is isolated from auditory language input; the patient can hear but cannot understand or repeat speech sounds. Except for the severely impaired input processing of speech, the patient with pure word deafness does not otherwise function like someone with Wernicke's aphasia. Auditory agnosia, which also reflects impaired processing of speech sounds, additionally reflects an impairment in processing non-language environmental sounds.

Agraphia

Agraphia, an inability to produce written language, has several neurolinguistic variants, which are discussed later in the neurolinguistic structures section. Functionally, it may appear as a written form of Broca's aphasia and, since written language so often mirrors spoken language, is typically associated with an aphasia. But, because writing also includes visuospatial skills as well as motor skills that differ from speech, impairments in spatial orientation or visual discrimination can cause agraphia without aphasia. Cases of pure agraphia frequently report damage within the frontal lobe, but a few cases have also shown damage within the left superior parietal lobe.

Alexia

Alexia is an acquired reading problem exhibited as an impaired ability to recognize words and/or letters, thus affecting the ability to extract meaning from written text. There are several varieties of alexia, including literal alexia (also referred to as letter blindness because the problem is primarily with individual letters), verbal alexia (also referred to as word blindness because whole words are primarily affected), general alexia (which refers to reading impairments that affect grammatical and/or semantic processing more than letters or words), and hemialexia, more commonly called neglect alexia (which refers to the impairment of attending to only half of a word or a line of text). In so-called pure alexia, written language stimuli are seen but not recognized as letters, as words, or both. In these cases, lesions tend to compromise the visual association cortex in the

language hemisphere together with the callosal fibers projecting from the other hemisphere, effectively isolating central language brain areas from visual input. There is a variant of pure alexia called letter-by-letter reading; such patients seem to process words by reading one letter at a time aloud before the word is identified. In some cases of alexia patients may successfully comprehend words if they are spelled out loud or traced on the palm, thus bypassing visual input to access the language core brain regions.

Transcortical Aphasias

The transcortical aphasias are sometimes known as the echolalic aphasias; there are three types, transcortical sensory, transcortical motor, and mixed transcortical, the latter sometimes known as the isolation syndrome. The modalities of language that are affected are speech comprehension (transcortical sensory) and speech production (transcortical motor) in the context of a sometimes dramatic spared ability to repeat, thus contrasting with conduction aphasia. In discussing the transcortical aphasias, it is useful to consider the notion of the language core, the temporo-parieto-frontal cortex of the language-dominant hemisphere in which resides the ability to repeat what is heard as well as the ability to process the basic sounds and word and sentence structures of one's language. Originally, the term transcortical meant that an ability to reproduce the sound structure or representation of a word was preserved, in the context of being unable to construct its meaning; this could be considered analogous to an ability to repeat a word in a foreign language that one does not understand. The predominant anatomically distinguishing feature of these aphasias is that the causative lesions are largely extra-Sylvian in location, that is, outside the classic language core. The following provides a brief overview of the generally accepted classical forms of the transcortical aphasias.

Transcortical Sensory Aphasia Transcortical sensory aphasia is an uncommon form of aphasia that may occur when a lesion functionally isolates Wernicke's areas from the rest of the brain, leaving the reception-to-output sufficiently unimpaired that repetition is preserved; neither speech comprehension nor spontaneous speech remain intact. The simplest way to describe transcortical sensory aphasia is to think of it as a form of Wernicke's aphasia in which the patient exhibits a severe comprehension deficit, but in which repetition, and thus articulation, is well preserved. In spite of intact articulation, the repeated speech of the transcortical sensory aphasic patient may be paraphasic, neologistic, anomic, and even echolalic. Typical output may appear to be uninhibited. Patients with transcortical sensory aphasia typically tend to be unaware of their impairment; as might be expected, their speech is occasionally misinterpreted as a psychogenic problem, such as schizophrenia. Writing ability is usually disturbed in a manner similar to that of patients with Wernicke aphasia.

Transcortical Motor Aphasia Transcortical motor aphasia, another form of the transcortical aphasias, is sometimes known as dynamic aphasia or anterior isolation syndrome. Functionally, the causal lesion separates the processing of speech from the mechanisms for initiating the action to speak. Patients with transcortical motor aphasia tend to appear mute, or nearly so, and may even have an associated general akinesia, an inability to initiate action. Although transcortical motor aphasia impairs the ability to initiate speech, once such patients begin talking, speech output is typically relatively intact. Comprehension will be relatively normal, as will repetition. Prosody, articulation, and grammatical structure remain quite preserved even if verbal output is interrupted by incomplete sentences, verbal paraphasias, or false starts. When asked to say something, or otherwise initiate a response without cues, these patients have a great deal of difficulty responding; however, when asked to repeat words, phrases, or sentences, performance is characteristically flawless. There is a range in ability in word retrieval, with some patients being able to perform well on tasks such as object naming. Verbal output may improve if related to common, repetitious material. The lesions that lead to transcortical motor aphasia are typically found on the mesial surface of the anterior left frontal lobe, near supplementary motor cortex, or along the lateral aspect of the left frontal lobe; in either case these lesions fall outside of what is traditionally thought of as Broca's area. Presumably the lesions impinge on an anterior cortical or subcortical site that forms part of a circuit linking the motor speech area with the supplementary motor area and certain limbic structures considered essential for the initiation of speech and other actions.

Mixed Transcortical Aphasia Mixed transcortical aphasia, known also as the isolation syndrome, may be associated with Pick's disease or carbon monoxide poisoning affecting the so-called watershed region of the cerebral vasculature; the language core, the peri-Sylvan speech areas, are functionally isolated from other brain functions, particularly higher-order cognitive functions. The one remaining language

function is a striking ability to repeat words, phrases, and on occasion whole sentences. The isolation syndrome is most clearly the functional opposite of conduction aphasia; the former patient can only repeat speech, while the latter cannot repeat speech. Although articulatory fluency generally remains well preserved, the quasi-automatic repetition, often a frank echolalia, is prominent in a context of few if any other intact language functions. There is typically a complete alexia and agraphia, with an occasional ability to scribble meaninglessly. As pointed out by Benson and Ardila, other than the ability to repeat, patients with mixed transcortical aphasia exhibit the characteristics common to global aphasia.

Neurolinguistic Structures

The second approach, a neurolinguistic analysis of the aphasias, focuses on which linguistic components of language are affected by brain damage, within the framework of five, sometimes six, components of language: (1) phonology, or the sound system, (2) morphology, or the structure of words, (3) syntax, or the grammatical system, (4) semantics, or the system of meaning, (5) narrative or discourse, or the component that strings sentences together in coherent syntactic and semantic structure, and (6) the pragmatic or language use system. Linguistic-based descriptions of aphasic errors are neutral as to whether the errors are seen in speech production or comprehension or in written language. It is typical that the degree of impairment (percentage of errors seen on testing) of linguistic components is different in different language modalities; for example, a Broca's aphasic patient is likely to exhibit more severe agrammatism in speaking than in comprehending. It is occasionally documented that the linguistic impairments are overwhelmingly in one modality (e.g., being able to recognize grammatical errors but being unable to avoid producing them); this can lead to interesting theoretical issues regarding the nature of the language core brain areas, which are beyond the scope of this article.

Phonological Disorders

Phonological disorders are typically described in terms of phonemes, the minimal significant unit of sound in a language, or graphemes, the equivalent for the writing system. Errors may be described as substitutions (e.g., *bit* for *pit*), omissions (e.g., *cook* for *crook*), or sequencing errors (e.g., *cattle* for *tackle*, as sounds). Other phonological errors include problems with the control of prosody: syllables may be shortened or lengthened incorrectly, pitch contours may signal a question when a statement was intended, or speech may be louder or quieter at inappropriate times.

Morphological Disorders

Morphological disorders affect a word's affixes, either (a) the inflectional affixes such as mark plural vs. singular, third person singular vs. first person singular, or past vs. present tense (e.g., *three cat* for *three cats*, *he will jumped* for *he will jump*) or (b) the derivational affixes such as mark words as nouns, verbs, or adjectives (e.g., *nationalness* for *nationality*).

Syntactic Disorders

Syntactic disorders, agrammatism, affect the grammatical structure of phrases and sentences. Obviously, if disorders of derivational or inflectional affixes discussed previously were to impact the grammatical correctness of a phrase or sentence (e.g., *he's a regularity guy* for *he's a regular guy*) one would speak of a syntactic deficit that manifested as a morphological error. The more common form of agrammatism is seen as the omission of grammatical function words (e.g., *boy hit ball* for *the boy was hit by the ball*), which clearly impacts the meaning of the sentence as well as its grammaticality; thus, as was the case with morphological disorders, syntactic disorders can overlap semantic disorders, too. A rarer form of syntactic disorder known as paragrammatism results in the inappropriate use and ordering of grammatical function words, rather than their omission (e.g., *in on a the by a flower pot* for *in the flower pot*). Additional syntactic disorders involve the simplification, ordering, substitution, or omission of phrase- and sentence-level structures that may interact with impairments in meaning. For example, if *what the pot put on the table was the boy* were substituted for *it was the pot that the boy put on the table*, or, *what the boy put on the table was the pot*, one would note that the grammatical errors of substitution and ordering resulted in a change in meaning. As will be readily surmised, agrammatism is frequently, though not exclusively, seen in Broca's aphasia; paragrammatism is less frequently seen in Wernicke's aphasia because word order violations are infrequently observed syntactic disorders.

Semantic Disorders

Semantic disorders can take any number of forms, depending upon what aspect of the semantic system is impaired. Substitution of similar-meaning words is common (e.g., *concert* for *orchestra*) as is the interchange of superordinates and subordinates (e.g., *animal* for *dog*). A common strategy for anomic patients is to substitute an indefinite noun for an inaccessible

one (e.g., *something* or *stuff* in place of *shirt* or *clothes*). Semantic disorders may also impair knowledge of features of objects (e.g., being unable to indicate that a fire truck is red or that grass is green) or attribute incorrect features to objects (e.g., something inanimate is given attributes of being alive).

Narrative Disorders

Narrative or discourse disorders will affect the coherent stringing of sentences or phrases together in conversation, for example, changing a pronoun so that it no longer refers back to the person who is being discussed or inappropriately changing the time frame of a narrative. Pragmatic disorders refer to impairments in language use, for example, no longer understanding that the statement "I could use some salt on my roast beef" is an indirect request to another person to pass the salt shaker to the speaker. It will be immediately apparent that, just as with morphological and syntactic disorders, higher level problems with discourse and pragmatics may be described in terms of semantic or syntactic errors. The different linguistic components of language, levels, are simultaneously present when language is being used.

Alexias

The analysis of neurolinguistic structures has led to a syndrome classification of reading and writing disorders as follows. Three alexias have been defined in terms of the putative locus in a psycholinguistic model of reading: deep alexia, phonological alexia, and surface alexia.

Deep Alexia Patients with deep alexia usually have sustained a lesion sufficiently large to produce an aphasia, frequently a Broca's aphasia; their reading is characterized by semantic errors in reading aloud (the error is semantically related to the target word) and may also show visual errors (the error is visually similar but otherwise unrelated to the target word), morphological errors (the error is a morphological variant of the target word), a concreteness effect (concrete words are easier to read than abstract ones), and difficulty in reading grammatical function words. Word frequency and word length may also impact the prevalence of reading errors. Patients with deep alexia are impaired in grapheme-to-phoneme conversion; as a result, they have a pronounced inability to read non-word letter strings that could be possible words in the native language (e.g., for English, the string *vib* or *phite*).

Phonological Alexia Phonological alexic patients can read real words but because they also have a major problem with grapheme-to-phoneme conversion, they have difficulty reading pronounceable nonwords, as is the case with deep alexic patients. Patients with phonological alexia typically do not make the semantic errors seen in deep alexia; otherwise, the boundary between deep and phonological alexia is not always sharp and some patients seem to have many characteristics of both types. It has been reported that deep alexia may evolve to phonological alexia in the course of recovery.

Surface Alexia Patients with surface alexia have a reading impairment characterized by their ability to read orthographically regular words (note that about 75% of the English lexicon is orthographically regular, e.g., words such as *top, jelly, sing*) but a pronounced difficulty reading orthographically irregular words (in English, words such as *pint, come, bury* are orthographically irregular). Errors made by surface alexic patients on irregular words tend to be regularizing errors, that is, pronouncing them as though they were orthographically regular. Surface alexic patients are able to read pronounceable nonwords, e.g., *heaf* would be read to rhyme with the word *leaf,* which is regular, but not *deaf,* which is irregular.

Agraphic Disorders

As with reading impairments, there are three main linguistic forms of agraphic disorders. The first is phonological agraphia, which is an impairment in writing pronounceable pseudowords to dictation, with a much better preserved ability to write real words and occasional difficulties with grammatical function words and abstract words. A second form is semantic agraphia, which can occur with focal lesions but is more commonly found in the early stages of senile dementia of the Alzheimer type; such patients may write real words and pseudowords normally to dictation, but they make frequent semantic errors in written confrontation naming or written descriptions. A third form is lexical agraphia; these patients preserve the phonological form of the word when writing, but produce spelling errors that normalize spelling to approximate to how the word sounds.

Conclusion

In conclusion, the main recommendations today for continued use of the functional/clinical aphasia syndromes, the so-called classical syndromes, reviewed here are convenience and consistency. A great deal of modern research in neurolinguistics, clinical neuropsychology, and the cognitive neurosciences employs the classical aphasia syndromes for identifying patient groups, notwithstanding the research in the late twentieth century that casts doubt upon the

validity of the consistent location of causative lesions, other research that questions the logical coherence of the symptomatology of syndromes, and still other research that questions the possibility of studying groups of patients classified in terms of these syndromes. The most widely used test battery in the United States, the Boston Diagnostic Aphasia Examination (BDAE), from which the major aphasia syndrome typology originates, claims to be able to classify only about three-fourths of all patients with language impairments. One may still argue, and many contemporary publications will attest, that the patients who can be so classified into syndromes can, sensibly and statistically, be grouped under these headings for research purposes. In contrast, a linguistic typology of aphasia, a classification of neurolinguistic impairments, would only be challenged by a better linguistic theory. Such a classification does characterize aphasic impairments even if it does not neatly align with functional and clinical categories, nor does it neatly align with particular brain regions as revealed by lesion localization or imaging techniques. Caveat emptor.

See also: Language and Communication in Aging; Language Disorders: General; Speech and Communication (speech styles).

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Language Disorders: General

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Glossary

Aphasia – Acquired, usually abrupt-onset language impairment resulting from brain damage.

Dementia – Acquired disorder of cognitive and self-management abilities, that may be characterized by progressive decline of memory, judgment, and abstract thinking, as well as changes in personality.

Discourse Skills – Skills allowing the appropriate use of pronouns, intonation patterns, and meeting social expectations in conversation.

Lexical Skills – Skills that relate to the production and comprehension of individual words.

Syntactic Skills – Skills that enable a person to understand and use conventional rules of grammar.

Overview of Language Disorders in Older Adults

Language disorders in older adulthood can be generally divided into progressive impairments of

language associated with dementing diseases and non-progressive, abrupt-onset aphasia. This article describes the language deficits associated with dementia syndromes and provides a brief review of language deficits in aphasia.

Dementia (*see* Dementia) is an acquired disorder of cognitive and self-management abilities, characterized in many instances by progressive decline of intellectual function involving impairment of memory, judgment, and abstract thinking, as well as changes in personality. Language impairment also accompanies most forms of dementia. Dementia predominantly affects older adults, and its prevalence rises with increasing age. Since a larger proportion of the population of today is older than in the past, and long-term survival is predicted to increase in the coming decades, the number of individuals with dementia is rising.

Different types of dementing disorders have been identified (e.g., dementia of the Alzheimer's type, frontotemporal dementia, vascular dementia), but differential diagnosis of these disorders is still clinically challenging, and the prevalence of the different disorders is not only difficult to ascertain but also controversial. At the present time, dementia associated with Alzheimer's disease is often considered to be the most prevalent form and is often said to account for 55% of all cases of dementia, with dementia with Lewy bodies accounting for about 15%, vascular dementia about 10%, and frontotemporal dementia about 5%. As diagnostic precision improves, these percentages will undoubtedly shift.

Researchers have asked whether dementia accompanies the normal course of growing old (*see* Language and Communication in Aging). If so, one or another form of dementia will necessarily occur, eventually, in any individual who lives long enough. If, by contrast, dementia is related to a disease state superimposed on the course of healthy aging, it would not be expected to occur in all individuals. Research evidence available today points to the latter proposition; that is, despite growing percentages of aging individuals who acquire dementia, the majority maintain most of their cognitive skills over time. Age alone, therefore, despite being a major risk factor, does not explain dementia.

Aphasia (*see* Language Disorders: Aphasia) refers to an acquired, usually abrupt-onset, language impairment resulting from brain damage. In contrast to dementia, behavior, personality, and other cognitive abilities are essentially preserved in aphasia. The leading cause of aphasia is cerebrovascular accident (CVA, or stroke), which results from a sudden disruption of blood flow to the brain, causing cell death. Such a disruption can be the consequence of obstruction of flow in the blood vessel or rupture of the blood vessel with bleeding into the brain. Strokes are the third most common cause of death among adults in the United States, and about two-thirds of all strokes occur in individuals who are 65 or older. About 20% of persons with stroke have aphasia, and it is estimated that approximately one million persons in the United States today have aphasia. Although the behavior and cognitive deficits of individuals with aphasia and dementia are fundamentally different, the term aphasia is sometimes used to refer to the manifestation of language and communication deficits in dementia.

Language in the Dementias

This section outlines the major dementing syndromes that are pertinent to aging and summarizes the language deficits that have been observed clinically as well as experimentally in individuals with these syndromes.

Dementia of the Alzheimer's Type

Dementia of the Alzheimer's type (DAT) is characterized neuropathologically by cerebral atrophy, predominantly in temporo-parietal, anterior frontal, and hippocampal regions, excessive deposition of amyloid plaques and neurofibrillary tangles, amyloid angiopathy, and granulovacuolar degeneration. Behaviorally, individuals with DAT exhibit progressive impairments in memory, attention, and executive function that lead to associated communication deficits. Other cognitive deficits include impairments of judgment and reasoning and are severe enough to interfere with daily functioning. Despite the considerable variability that can be found among individual patients, some generalizations about language and communication skills can, nonetheless, be made. The following sections review the changes in lexical, semantic, syntactic, and discourse skills typical of DAT.

Lexical Skills Lexical skills are those that relate to the production and comprehension of individual words. Even in the earliest stages of the disease, patients with DAT show evidence of lexical impairment but are often unaware of this difficulty. For example, they may replace target words with less meaningful fillers (such as *thing*), confuse semantically related words (e.g., *dog* for *cat*), produce names that would be correct in another context (e.g., *jelly jar* instead of *cookie jar*), or generate a novel expression in place of an accepted noun (e.g., as Alois Alzheimer's original patient did, saying *milk pourer* for *cup*). They

may also show difficulties in elicited word retrieval tasks such as confrontation naming (naming a picture or an object upon request) or word list generation (generating as many words as possible, given a letter or a semantic category, within a given time). Typically, letter-based word list generation is more impaired than semantic-based generation in DAT. Performance differences may exist by response modality. For example, a person who does well at oral naming may have extreme difficulties with written naming.

As the dementia progresses, word retrieval problems become more pronounced. Frequent instances of circumlocution (describing a target instead of using the word itself) often make the language production of individuals with DAT difficult to follow, and their own awareness of their problem tends to diminish as other cognitive skills decline. In even later stages, production errors may include sound substitutions or non-words (neologisms), as well as semantic substitutions. Lexical skills become progressively worse with time, and by the end stages of DAT, some patients are unable to produce their own names.

Problems using words correctly in conversation are thought to be due, at least in part, to short-term memory deficits, as patients with early stage DAT frequently forget what they are saying. However, their lexical problems cannot be fully explained by a loss of short-term memory or loss of semantic knowledge (the knowledge of what things are). Rather, researchers have shown that people with DAT who cannot name an item on their own are more likely to choose a semantically related word rather than an unrelated word, if given several choices. Furthermore, they are often able to identify objects when provided with a name. Researchers have taken these experimental observations as evidence that, at least in the early stages of DAT, many elements of semantic knowledge are intact, but that the ability either to discriminate among several related items or to choose the intended word produces the word-finding difficulty.

Syntactic Skills Syntactic skills are those that enable a person to understand and use conventional rules of grammar. Researchers generally report that the syntactic abilities of people with DAT remain intact. However, by late-stage DAT, patients exhibit spoken comprehension difficulties and can rarely follow multistep commands. Their ability to comprehend written material is difficult to judge because of the difficulty that reading aloud poses for them. Furthermore, some studies have shown that people with DAT may have difficulty understanding and producing syntactically complex structures, such as subordinate clauses (e.g., "The truck that pulled the car was blue."). Memory problems are likely to contribute to these deficits. Although language output may become progressively more fragmented, many speakers with DAT are able to produce grammatically complex sentences through the middle stages of the disease. As with other language skills, syntactic knowledge in DAT does not seem to disappear, but its use appears to be severely hampered by the cognitive problems associated with the progression of the dementia.

Discourse Skills Discourse skills include the knowledge of language use at the conversation level, including verbal aspects of conversation, such as referential coherence (e.g., appropriate use of pronouns), and non-verbal aspects, such as prosody (intonation patterns) and social expectations. In DAT these skills are usually intact until the later stages of the dementia. While turn taking and the prosody of the speech remain normal, individuals with late-stage DAT show an increased tendency to violate conventions of topic maintenance and shifting, abruptly changing the topic or failing to signal their interlocutor appropriately. They are also much more likely than non-demented speakers to mention things that are inappropriate for the setting or to misinterpret the interlocutor's questions (e.g., during a naming test, a patient was asked whether he knew what an object was called; the patient replied "Yes, why do you ask?"). In addition, their discourse may become fragmented due to the impaired use of referring expressions. For example, to the question "Do you remember me?" a patient answered "I've seen it I think, I hope," using the pronoun *it* inappropriately. Similarly, individuals with DAT may refer to the same person as *he* and *she* within a single sentence. These deficits are thought to be at least partially due to memory deficits that prevent the speaker from remembering, and then correctly referring to, his or her utterances over the course of the conversation. Often, individuals with DAT respond to social greetings and are able to give their names when asked, even in advanced stages of the dementia.

Non-Alzheimer's Dementias

Frontotemporal Dementias The frontotemporal dementias (FTDs) are a group of syndromes characterized by progressive degeneration of the frontal lobes, the temporal lobes, or both. A prominent characteristic of FTDs is personality change, manifested in impaired social interaction, loss of insight, and self-neglect. Frontal-executive skills are impaired, and memory retrieval may be impaired, often as a consequence of frontal-executive deficit. Individuals with greater left hemisphere involvement

experience greater language impairment, whereas those with greater right hemisphere deficit show relatively intact language and speech skills (although their affect and communicative facial expressions might be impaired).

Language-related changes associated with FTDs include reduced speech output, repetitive and habitual use of single words or phrases (stereotypy), and an increased use of automatic speech. In later stages of the dementia, the speech production of individuals with FTDs is characterized by involuntary, spontaneous repetition of their own words (palilalia), other speakers' words (echolalia), and previously used words or phrases (perseveration). Also common are repetition of final syllables (logoclonic speech) and rapid reiteration of individual phonemes (festinant speech). Language impairment comprises severe word-finding difficulties (anomia) and reduced verbal fluency. As the dementia progresses, there is often a gradual progression to mutism. Although language comprehension appears less impaired than language production, in many individuals with FTDs, spoken language comprehension can be affected. Research studies of language comprehension have found that on auditory comprehension tests, individuals with FTDs are insensitive to transitivity and thematic agreement. For example, on a word-detecting test, healthy older adults respond faster to a word that is consistent with the thematic constraints of the preceding sentence than to a word that is inconsistent with the theme (e.g., responding to the word *carpet* after hearing: *the plaster falls onto the carpet* as compared to after hearing *the thought falls onto the carpet*). By contrast, individuals with FTDs do not exhibit slower response times with the latter type of sentences (i.e., with incorrect thematic agreement).

A subgroup of individuals with FTDs consists of those with primary progressive aphasia (PPA). In the first 1 or 2 years of this syndrome, a language deficit emerges, but memory and social and behavioral skills are preserved. Speech impairments include articulation difficulties, stuttering, and gradually reduced speech output, often progressing to mutism. Most patients with PPA experience anomia, with verb naming often more severely impaired than noun naming. Furthermore, research evidence suggests that in object naming, both natural kinds (e.g., *horse, tree*) and manufactured objects (e.g., *table, spoon*) are impaired, and there is differential impairment on these different subcategories.

Individuals with PPA can be divided into those with non-fluent aphasia and those with fluent aphasia (also known as semantic dementia). These two subtypes share many aspects of language disturbances but can be distinguished on the basis of their relative difficulty with word list generation (known also as verbal fluency), object naming, and single word comprehension, and the sound substitutions (phonemic paraphasias) they produce, as described in the following.

Frontotemporal dementia of the frontal type Among individuals with PPA, asymmetric cortical atrophy and frontal lobe degeneration can result in progressive non-fluent aphasia (PNA). Initially, PNA causes a slowly progressing language impairment, with little additional cognitive decline. Speech production is often slow, hesitant, and effortful. Articulation difficulties (dysarthria) may be present and are more likely as the disease progresses. The language impairments include phonemic paraphasias and anomia, although the anomia is less severe than that seen in semantic dementia. Utterances tend to be short due to difficulty with complex sentences, such as those containing relative clauses. Language comprehension is relatively preserved. Reading aloud is effortful, and sound substitutions are common. Writing skills are also impaired, characterized by frequent spelling errors.

Frontotemporal dementia of the temporal type Semantic dementia (SD) is the fluent type of progressive aphasia and is primarily associated with temporal lobe involvement. As in PNA, the onset of semantic dementia is insidious and the course of the impairment is progressive. SD is characterized by effortless, fluent, grammatical speech. Repetition and writing skills are basically intact. By contrast, word production (e.g., in picture naming) and word comprehension are impaired. As in fluent aphasia (*see* Language Disorders: Aphasia), speech often appears empty, due to the increased use of vague terms. Word substitutions (semantic paraphasias) are common, especially as the dementia progresses. Researchers have pointed out that the lexical deficit in SD can indicate loss of semantic knowledge. Evidence for this can be found in the semantically based word production errors and in word and object recognition errors produced by individuals with SD.

Individuals with semantic dementia have difficulty producing irregular past tense forms (e.g., *break–broke*) but perform at near-normal levels with regular verbs (e.g., *visit–visited*). This is consistent with research findings suggesting that irregular verb forms are represented as words in the lexicon, whereas regular verb forms are produced by the grammar. Similarly, irregular verb production (but not regular verb production) correlates with the ability to judge verb synonyms (i.e., whether two given verbs have roughly the same meaning), suggesting semantic,

rather than syntactic, impairment. Furthermore, more individuals with SD show greater impairment on naming tests than those with PNA or other subtypes of FTDs. People with SD also show a significant correlation between naming and performance deficits on semantic memory tests as well as impaired performance on word list generation tasks, consistent with a memory deficit basis for the naming impairment.

Movement Disorder-Related Dementias

Parkinson's disease dementia Individuals with Parkinson's disease (PD) are more likely to have dementia (PDD) than are age-matched persons without Parkinson's disease. Reports estimate that the percentage of individuals with PD who exhibit dementia ranges from 15 to 40%. PDD typically develops slowly, often with modest and variable decline. Motor slowing and impaired movement programming associated with PD often affect speech production. Speech deficits include monotonous speech (dysprosody), reduced phrase length, low intensity of speech (hypophonia), and dysarthria.

Generally, language skills have been considered to be intact in early PDD, gradually declining only as the dementia progresses. However, investigators have demonstrated that in language production, individuals with PDD have mild naming and word list generation deficits. As in individuals with DAT, semantic-based production is better than letter-based production. Output is characterized by frequent pauses and hesitations, but few word substitutions. Syntactic skills remain essentially intact in PD, but in PDD, grammatical ability varies with the severity of the dementia. When written language production is examined, using samples of one sentence and measures such as length in words, length in clauses, number of propositions, and number of fragments, individuals with moderate PDD differ from healthy older individuals. By contrast, individuals with PD without dementia or with mild PDD have not been found to decline on any of these syntactic measures. Working memory limitations, reduced processing speed, or visual impairments may contribute to comprehension deficits on tests such as picture identification. When auditory probes are used in a listening comprehension task in people with PDD, participants may have difficulty detecting a missing grammatical morpheme but are able to detect word order errors. They perform well with passive structures and transitive verbs but have trouble with lexical causative verbs (e.g., "The woman drowned the swimmer").

Dementia with Lewy bodies The diagnosis of dementia with Lewy bodies (DLB) is based on the presence of intracellular hyaline inclusions (Lewy bodies), found in cortical and subcortical brain regions of a subset of individuals with PD. The distinguishing characteristics of DLB are parkinsonism, visual hallucinations, and fluctuating cognitive impairment.

Relatively few reports have focused on the language of individuals with DLB. Speech production might be impaired to the extent that parkinsonism is present, with decreased volume and rate of speech. Whereas language itself is not typically impaired in DLB, impaired executive skills and reduced cognitive speed contribute to compromised language skills. For example, individuals with DLB may experience difficulty producing words and phrases during testing, but this difficulty is likely due to executive skills rather than frank language difficulty. Such difficulties include poor performance on word list generation tests, with no greater deficit on semantic- than on letter-based productions, and mild deficits in confrontation naming. Perseverations are also common. Additional limitations include decreased attention and poor search and working memory skills, which might interfere with efficient language use. Fluctuations, which characterize cognitive abilities in DLB, characterize these verbal difficulties as well.

Huntington disease dementia Huntington disease (HD) is characterized clinically by jerky movements (chorea), slow writhing movements (atheosis), repetitive movements, and twitching. As the disease progresses, breathing and articulation impairments disturb speech production and yield dysarthria, dysprosody, and decreased speech volume, rate, and phrase length. In HD, speech is characterized by markedly decreased initiation and short, grammatically incomplete sentences. Clinically, frank language deficits are not typically associated with HD, but communication abilities may be affected due to cognitive impairment, including decreased ability to shift set, impaired attention and memory, and decreased organizational skills. These cognitive deficits have been linked to impaired word list generation, both semantic- and letter-based production (performance is typically better on the semantic-based task), and impaired naming. This is true particularly as the dementia advances, although difficulty on naming tests has been reported even when the dementia diagnosis is mild. Moreover, in studies comparing individuals with late-stage HD and DAT, people with HD do not perform better than those with DAT on measures of language comprehension, speech perception, and vocabulary. As the dementia develops, verbal output is severely decreased, progressing eventually to mutism.

Vascular Dementias The vascular dementias (VaDs) include several dementing syndromes resulting from cerebrovascular insufficiency: multi-infarct dementia, single strategic strokes, multiple subcortical lacunar strokes, white matter lesions, postischemic dementia, and vascular-Alzheimer dementia. Although grouped together, there is great heterogeneity among the differing vascular dementias.

Relatively few studies have examined language deficits associated with the vascular dementias. Existing data suggest that poor executive function might affect planning, sequencing, and attention during task performance. Memory impairment might lead to impaired performance on naming tests, but such deficits are not always found. Little is known about the language of VaDs of the multi-infarct dementia type, primarily because individuals with vascular impairment who are diagnosed with aphasia are normally excluded from studies of vascular dementia, to avoid confounding the focal deficits of aphasia and those of dementia. For individuals with VaDs resulting from a single stroke, the location of the stroke will influence the language impairment that might follow. In individuals with white matter lesions (WMLs), decreased verbal retrieval, reduced spontaneity, and laconic speech with reduced syntactic complexity may be present. Additional frank language deficits associated with VaDs include decreased word list generation, particularly for letter-based production, reduced sentence complexity in language production, and frequent perseverations.

Developmental Disorders and Dementia

Until recently, relatively little had been written about the neuropsychological functioning of individuals with mental retardation (MR) who subsequently develop dementia. With the increasing life span of individuals with MR, clinicians and researchers have begun accumulating data about age- and dementia-related changes in individuals with MR, particularly those with Down syndrome (DS). There is substantial evidence suggesting that dementia, especially dementia of the Alzheimer type, is highly prevalent among individuals with DS. Studies of neuropsychological impairment of individuals with DS who develop dementia demonstrate that their cognitive impairment is similar to that found in the dementia syndromes of the general population. Areas of cognitive decline include memory, naming, semantic fluency, and comprehension skills.

Behaviors associated with dementia, mostly with DAT, may develop in individuals with DS at a relatively early age (as young as 40 or 50 years). It is often difficult to dissociate cognitive deficits associated with the dementia from those that pre-existed in the aging individuals due to their developmental disorder. This difficulty is compounded by the great variability of intellectual abilities found among individuals with DS and MR generally. Furthermore, commonly used tests for dementia diagnosis are usually inappropriate for diagnosis among individuals with MR. Researchers have begun to demonstrate that certain neuropsychological tests, including tests of short-term memory, confrontation naming, and word list generation, can be sufficiently sensitive to distinguish between individuals with MR with and without dementia; however, normative data for cognitive skills and particularly for language skills are still necessary.

Multicultural Aspects

Cultural Considerations Data concerning the prevalence and characteristics of dementia across cultures and languages, especially in developing countries, are sparse. Recent reports suggest that by employing cognitive and language measures adapted to several languages, as well as informant information, clinicians can efficiently assess the dementing syndromes among a variety of communities. These reports are preliminary, and experts agree that normative data from a wide range of cultures and languages are still lacking. This dearth of norms might lead to misdiagnosis.

Whereas the majority of data available in the United States today is about Caucasians, recent work has focused on dementia among non-white Americans, including Asian Americans, Hispanic Americans, African Americans, and Native Americans. Dementia prevalence has been reported to be higher among African Americans and American Hispanics than among Caucasian Americans. Reports also suggest that there might be differences in the prevalence of the various dementia types among the different ethnic groups. Differences may be attributed to environmental, social, and biological factors, and to measurement differences.

People of Hispanic, Asian, and Native American communities may be less likely to be aware of resources for patients and caregivers and may be less likely to seek medical support. Moreover, fewer resources (professionals, diagnostic materials) adapted to the culture and language of minority communities are available. As a result, persons in minority communities are often less informed about the dementing syndromes, their etiology, and symptoms. Furthermore, attitudes toward individuals with dementia vary across cultures. In some cultures, stigmas might be associated with dementia and the symptoms associated with it. They can be considered shameful

or be attributed to 'bad blood,' being punished for previous sins, or mental illness. In some cases, dementia symptoms are attributed to normal aging, and respect for the elderly would prevent seeking external help. Such cultural differences have started to be considered in assessment and treatment of individuals with dementia.

Bilingual and Multilingual Speakers To date, evidence on language disturbances in bilingual dementia is limited. Individuals who speak two languages and acquire dementia have been found to exhibit the same patterns of language impairment found in monolinguals with dementia. For individuals who have high proficiency in both their languages, the two languages appear to be equally affected. But, as in bilingual aphasia, there are individuals who demonstrate differentially impaired skills in their first or second language. Little is known about individuals who use more than two languages (multilinguals).

Those impairments observed among bilingual individuals with dementia include inappropriate language choice and language mixing. For example, inappropriate language choice occurs when individuals (unintentionally) speak one of their languages with an interlocutor who only understands the other language, or reply in a language different from the one in which they were addressed. Language mixing (code mixing) refers to a situation in which the individuals mix words and utterances from both languages, even when the listeners are not able to comprehend both languages. At least in early stages of dementia, bilingual individuals are able to follow a conversation in any one of their languages, even if they reply in another. Preliminary research data suggest that the degree of inappropriate language mixing is not directly related to the degree of the dementia severity. Mechanisms that account for language choice in dementia are not well understood and represent a fruitful area for further research.

Language in the Aphasias

Aphasia (*see* Language Disorders: Aphasia) refers to language-specific deficits resulting from brain damage, usually in the left cerebral hemisphere. In most instances of aphasia, not all language skills are equally affected. Several types of aphasic syndromes have been identified. The classification of aphasia has been based, traditionally, on the type of language deficit observed as well as the location of the brain lesion. Whereas links between the type of deficit and lesion location have been identified, these relations are complex and are still debated.

Language impairment in aphasia may affect predominantly language production or language comprehension, one modality (e.g., spoken language) or all modalities, and may be mild or severe. Most speech-language clinicians and researchers today distinguish between two major categories of language disturbance. Fluent aphasia is typically characterized by fluent but empty (meaningless) speech production, word-finding problems, speech errors, semantic deficits, and impaired comprehension. Non-fluent aphasia is characterized by effortful speech and language production and relatively intact comprehension. In most cases, an aphasic impairment is not progressive, and time, practice, and treatment result in gradual improvement of language skills.

Several epidemiological studies of aphasia in adulthood demonstrate that certain forms of aphasia are associated with particular age ranges. Specifically, non-fluent aphasia has been associated with younger age ranges than fluent aphasia. In one study, for example, individuals with non-fluent aphasia were in their 30s to 60s with a mean age of 52, whereas individuals with fluent aphasia tended to be older, with an age range of 40 to 80 and a mean age of 63. This distribution might be related to brain changes associated with aging. The relation between age of aphasia onset and degree of recovery from aphasia, however, is less consistent. The hypothesis that older adults with aphasia are less able to recover their language skills than younger adults has not received unequivocal research support.

See also: Dementia; Dementia: Alzheimer's; Language and Communication in Aging; Language Disorders: Aphasia; Memory.

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Learning

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Glossary

Association – An association between two events is inferred when a subject reliably produces one event when presented with the other.

Conditioned Response (CR) – The learned response conditional upon presentation of the conditioned stimulus (CS), and previous pairings of the CS and unconditioned stimulus (UCS).

Conditioned Stimulus (CS) – Originally neutral stimulus that comes to elicit a response by being paired with the unconditioned stimulus (UCS).

Learning – The process that results in a relatively permanent change in behavior potential due to experience.

Paired-Associate Learning – A learning task involving pairs of stimuli. The subject is presented with the first item of each pair and is expected to produce the second.

Unconditioned Response (UCR) – The response produced by the unconditioned stimulus (UCR).

Unconditioned Stimulus (UCS) – A stimulus that has the ability to elicit a response without prior training.

Introduction

The area of learning encompasses a wide variety of tasks, from motor skills such as driving and typing to verbal tasks such as learning one's native or a new language or simply learning to pair a new friend's face with her name. This article presents a brief summary of research and theory in the area of learning and aging.

Learning is often defined as 'the process by which long-lasting changes occur in behavioral potential as a result of experience with various tasks.' Several of the terms in the definition need further explication. 'Learning' typically refers to the process by which change occurs; memory refers to the outcome of that process. 'Long-lasting' is used to distinguish learning from other more transient changes that may look like learning but are not; fatigue, motivational changes, and changes due to drugs are some examples. 'Behavior potential' is used because non-learning factors (e.g., motivation, opportunity to display the behavior) may not allow the changes to be expressed immediately. 'Tasks' is an omnibus term encompassing a diverse set of activities that can and have been studied, some examples of which are in **Table 1**.

The area of learning must also be distinguished from its companion area, memory, which Anderson (2005:5) defined as "the record of the experience that underlies learning." It should be apparent that the difference between these two areas is often subtle, perhaps arbitrary, and certainly debatable. It is also true that they are inextricably linked: without learning, there would be nothing to remember; without memory, learning would be for naught. A working distinction, to be adopted here, is that one studies learning when the focus of the investigation is the acquisition process itself, whether the material or skill being acquired is novel or familiar. Operationally, learning is the focus when the time period between the study or practice portion and the test portion is equal to, or less than, the time taken for the study phase.

For example, in a typical learning experiment, a list of 35 common words is presented on a tape recorder at the rate of one word every 5 s. After presentation, subjects are given 2 min to verbally recall as many of the words as possible. The list is then repeated, and again recall is attempted. This entire study–recall sequence is repeated five times. Although the list is composed of common words, that is, words already in memory, the focus of the study is the increase in recall (i.e., learning) across the five trials. Adding a sixth recall-only trial 20 min after the fifth study–recall cycle would have introduced a memory component to the task.

Rationale and Theory

Psychologists are interested in the relationship between aging and learning for several reasons. On a practical level, the proportion of the population over 60 is growing, and we need to determine how the learning processes of older adults differ from those of younger adults. Knowledge of these differences will allow us to develop effective ways to teach older people new skills, whether for the workplace, for treatment of various physical or psychological problems, or simply to help people deal with, and get more enjoyment from, their ultimate retirement. In

Table 1 Types of learning and examples of research and everyday responses

Type of learning	*Research tasks and responses*		*Common examples*
	Animal research	*Human research*	
Classical conditioning	Eyeblink Fear Taste, aversion Salivation	Eyeblink Galvanic skin response	Desensitization therapy Phobias Prejudices Food aversions
Operant conditioning	Bar pressing (rats) Key pecking (pigeons)	Key pressing Digit-symbol substitution	Behavior therapies
Instrumental learning	Multiple-choice-point spatial maze	Multiple-choice-point paper maze	Navigate in a new environment
Motor-skill learning	None	Typing Pursuit rotor Mirror tracking	Typing Bicycle riding Playing golf
Implicit learning	None	Artificial grammar learning Serial reaction time	Learning to speak one's native language as a child Skill learning requiring sequenced movement to specific stimuli
Paired-associate	Discrimination learning	Learning a list of noun pairs Learning a list of picture-word pairs	Foreign language vocabulary Face–name learning

addition, there is some concern that the retirement of older, highly skilled people might leave vacancies that could be filled only after extensive periods of training, prompting the idea that these older employees may be asked to remain on the job past their planned retirement time. Thus, additional training might be required for those individuals, especially when methods, materials, or equipment change.

On a more basic research level, one way to understand a process is to compare the process under two conditions: when it is working efficiently, and when it is not. Careful comparison of those two situations may yield insight into how the process works. Studying the effect of the aging process on learning may give us some insight into the learning process in general.

Finally, study of aging and learning allows psychologists to test theories of learning. Many theories of learning make predictions involving individual differences. For example, one theory might predict that physical activity is related to mental alertness. A preliminary test of the theory would be to determine if there were a correlation between some measure of physical activity and a measure of mental alertness. While finding such a correlation would be only modest support for the theory, not finding the correlation would likely doom the theory. Making different theoretical predictions for younger and older adults will allow us to test many different theories of learning.

Over the years, many theories have been developed to explain the fact that elderly adults typically perform more poorly than younger adults on various tasks. There are currently three primary theoretical orientations guiding research in the area of 'cognitive aging' that can be applied to the area of learning. These orientations are briefly described here, and are mentioned where appropriate in the remaining sections. It should be clear that no one approach adequately explains all of the data concerning age-related changes in learning.

Speed of Processing

As organisms age, various parts of the system slow down, including the speed at which nerve impulses are conducted, motor movements are initiated and completed, and mental operations are conducted. Slower responses mean many tasks take longer to complete or can not be completed in the time available. Thus, on tasks that require speeded responses or faster pacing, elderly adults are at a disadvantage relative to younger adults. Speed of processing is usually measured on simple perceptual tasks, and performance is then related to other cognitive tasks. A large body of research indicates that more of the age-related variance on the cognitive tasks is accounted for by the speed factor than by other possible mechanisms, including cognitive capacity. This theory can also explain some age $\times$ complexity interactions. If a simple task requires only one component, then the age-related speed difference on that component will result in a small difference in performance. If a complex task requires three successive processes and each is slowed by the same amount, the result will be a threefold age difference on the complex task relative to the simple task, an age $\times$ task complexity interaction. This approach is often the benchmark against which other theories are measured, but it does not explain all results. In addition, although the studies that support this theory employed many subjects, the data are correlational, making causal inferences problematic.

Limited Resources and Self-Initiated Encoding

Craik and other theorists have argued that age-related differences in various learning and memory tasks are the result of age deficits in the capacity to process information. Because attentional or working memory capacity is limited, those limited resources are allocated to various tasks as required. Some tasks (e.g., extracting frequency of occurrence information) are more automatic and require minimal capacity, while others (e.g., making visual images, learning a list of words) are more effortful and may require substantial cognitive resources. As we age, for whatever reasons, the attentional capacity, or the capacity of working memory, decreases. Thus, an effortful task that requires 80% of the processing resources of a young adult may require 95% of the resources of an older adult. Additionally, reduction of processing capacity results in more reliance on external factors, specifically, the environmental support provided by the task and the encoding and retrieval situations. Because of diminished capacity, older adults are less able to carry out resource-demanding operations, which include self-initiated operations such as mediation, organization, elaboration, or creation of novel connections. Thus, on tasks such as recall or learning new face-name pairs, which require effortful processing, the elderly are at a distinct disadvantage. However, when tasks provide sufficient environmental support, as in recognition of faces, age-related differences are reduced. This orientation also leads to the prediction that elderly will come to use more routinized, less demanding mechanisms for dealing with novel learning situations.

Although this approach has been useful in guiding research, different measures of working memory do

not correlate with other measures of capacity and do not consistently show age differences. In addition, other experimental results are not easily explained by this theory.

Inhibitory Control

Hasher, Zacks, and colleagues have proposed that differences in performance on many tasks can be attributed to age-related differences in "attentional inhibitory control over the contents of working memory" (Zacks, Hasher, and Li, 2000: 296). This approach has as its basis the idea that the performance of many tasks may be complicated by the presence of extraneous, irrelevant, or misleading stimuli, and to perform well on such tasks requires that responses to those stimuli must be eliminated or reduced. These irrelevant stimuli may be external, such as noises or voices, or internal, such as thoughts or feelings. Inhibition reduces the impact of these irrelevant stimuli in one of three ways: (1) by denying them access to working memory, (2) by deleting them from working memory, or (3) by restraining strong but situationally inappropriate responses, thus allowing consideration of less probable, weaker but more appropriate responses. Failure to inhibit attentional responses to these irrelevant stimuli leads to interference and subsequently to degradation in performance. The theoretical assumption, based on research evidence, is that with increasing age comes a decreased effectiveness of these inhibitory processes. Thus, in situations in which these irrelevant stimuli need to be inhibited to foster efficient learning, the elderly would be at a disadvantage. However, in situations in which those previously irrelevant stimuli subsequently become relevant, the elderly might have an advantage.

Non-associative Tasks

Research in the area of learning can be organized in various ways. For the purposes of this article, we will divide research into two primary categories, associative learning and non-associative learning. Associative learning can take various forms, all of which involve two events and the relationship between them. Although non-associative tasks may, on some level, involve two events, they are marked by the conspicuous absence of a relationship. Each category can be partitioned into subcategories, and in each of the subareas, where appropriate, research with both animals and humans is discussed.

Skill Learning

The prototypical example of the skill learning class of tasks is motor skill, or perceptual motor learning. These tasks require coordinating fine motor skills with the perception of sequential stimuli. In many instances these skills are learned in youth and, through continued practice, become very overlearned and automatic. A skill that has become automatic requires very little in the way of cognitive resources and thus can be maintained at reasonable levels even when cognitive resources have been greatly reduced, by either age or illness.

There is no doubt that increasing age brings with it a general slowing of responses. This slowing is evident in simple and choice reaction time tasks, and in other measures requiring speeded responding. Any theory of learning must be able to explain not only the generalized slowing with age, but also the fact that the slowing is even more pronounced for difficult or cognitively demanding tasks.

Research on motor skill learning has used both real-world tasks (typing, computer skills, archery, etc.) and laboratory tasks. As in any area, use of real-world tasks allows for ready generalization of the findings to those tasks, but also introduces a number of potential confounds that may be difficult to remove. Laboratory tasks, on the other hand, provide greater control over potential confounding variables, and also permit component analysis of the task. That is, with appropriate manipulations and theory, one can break a complex skill into its component processes. Examination of the separate processes allows for determination of those processes sensitive to aging and those that might be less sensitive, or even age insensitive.

Research using tasks that are sensitive to knowledge of results and that require discrete and precise movements, such as moving an object or moving one's hand a specified distance, show a main effect of age. The elderly start at a disadvantage relative to young subjects, but their rates of learning are comparable. As might be expected, when no knowledge of results is provided there are no age differences: there is little improvement in either age group. Although examination of task-specific processes may lead to identification of processes or variables exhibiting age-related declines, it is clear from a great deal of research that while many variables exhibit age-related declines, only a limited number of theoretical explanations will be necessary.

Given the increasing importance of computers for everyday living, it is not surprising that there has been research on learning to use computers. Basically, results indicate that the elderly can learn to use computers, but that the learning process takes longer and involves more errors in training than for younger subjects. Because of the complexity of this task, it will take a substantial amount of research to isolate

the important components. While some of the current research on computers and aging has involved skill learning, more attention has been focused on the attitudes of the elderly toward computers and ways to motivate the elderly to take classes or learn the skills. Other research has looked at ways to structure programs and training to facilitate learning and reduce the trepidation involved in approaching a new task.

Laboratory investigations have employed pursuit rotor, mirror tracing, or problem-solving tasks involving motor skills. For example, in mirror tracing, the subject is instructed to trace a figure (often a star) using only the information gained from the view of one's hand in a mirror. Tasks like mirror tracing produce larger age-related decrements than simpler tasks. It seems likely that the large age decrement may be due to the heavy cognitive component of the task. To trace an object using the mirror image requires that the subject mentally rotate the image and then translate that information into a hand movement. Thus, the task is analogous to performing in a dual-task situation, for which it has been consistently found that the age-related decrement on either task is greater than that for each task separately. These results are consistent with the idea that relative to younger adults, the elderly have reduced cognitive capacity to apply to various tasks. Other research has indicated that because aging brings a loss of motor control, elderly adults often take more time to perform various motor actions because they focus on accuracy rather than speed. Thus, the elderly spend longer on a movement or task because they are trying to be accurate and error-free. However, even when controlling for this tendency, elderly still take longer than young adults.

Other research on the effects of expertise are also consistent with the speed of processing explanation. A comprehensive study utilizing skilled typists ranging in age from 20 to 70 years found that when typing rate was measured by inter-key interval, the regression line relating typing to age was essentially flat. There was no relationship between age and typing rate. For the same typists, however, there was a strong positive relationship between age and choice reaction time. The typical age-related slowing was apparent in the choice reaction time task, but not on the typing task. Thus, it appeared that the subject's expertise led to an exception in the area of expertise. Because of the control afforded by the laboratory experiment, it was determined that the compensatory process responsible for this exceptional behavior was that older typists were more sensitive to characters farther in advance. Because the motor skill portion of the task was automated, the older typists were able to commit some of their free cognitive resources to the task of translating letters into movements. Similar compensatory mechanisms may be seen in other areas in which skills can become highly automated, such as reading, driving, or operating some machinery.

Because the typing tasks were performed under controlled laboratory conditions, there were few distractions. It is not clear how the results would have turned out had subjects also had to deal with distractions such as conversations or other noises. To the extent that subjects would have had to use some of their cognitive resources to block out or otherwise deal with the extraneous stimuli, one might expect a decrement in typing speed, with a greater decrement for the elderly. By appropriate design of experimental conditions one could conceivably test different predictions generated by the cognitive resources and inhibition theories.

Implicit Learning

Implicit learning refers to the process of acquiring knowledge about the structure of the environment without conscious awareness, or 'the non-intentional acquisition of knowledge about structural relations between objects or events.' Much of the research in this area has utilized either artificial grammar learning or serial reaction time (SRT) task.

In artificial grammar studies, subjects study letter strings, or in some cases figural sequences, generated by an artificial grammar. After the study phase, they are asked to classify new strings as grammatical or non-grammatical, which both young and elderly are able to do at greater than chance levels.

There are two interpretations for this learning. One is that subjects abstract the rules governing the task from instances of the task, not unlike children learning to speak their native language, without conscious effort. The second interpretation is that subjects learn the covariation of bigram and trigram sequences in the instances, rather than the rules. Because artificial grammar studies require many controls and conditions that have not always been utilized, and because of the interpretation difficulties, many investigators use SRT tasks.

In SRT tasks, subjects are presented a series of symbols, often asterisks, in positions on the computer screen and are required to press a button corresponding to the location of the asterisk. Across the practice trials there may be a series of blocks that contain a repeated pattern of locations and therefore of button presses. When the sequence is random, there is a small decrease in the reaction time, due to practice on the task. However, on the repeated

patterns, both young and elderly show the same increase in speed of responding. Appropriate controls indicate that this increase in speed is due to learning the specific patterns. The fact that there are no age differences on this measure while there are age differences in SRT tasks in which subjects are explicitly asked to predict in advance the location of the asterisk is taken as a measure of implicit learning.

Results of SRT studies indicate that there are age differences when the task is relatively difficult or when subjects are of relatively low ability. Results of some studies are consistent with the interpretation that age-related differences are due to differences in working memory.

Age-related differences in implicit and explicit learning may best be explained by referring to two mechanisms. Age-related differences in efficiency of processing speed may explain age differences in many explicit and implicit learning tasks. Preservation and use of certain mechanisms (e.g., chunking, unitization) may explain the lack of age differences on implicit and explicit tasks that are simple or are well learned or automated.

Associative Tasks

Classical Conditioning

In classical or Pavlovian conditioning, the unconditioned response (UCR) is naturally elicited by the unconditioned stimulus (UCS). For example, an eye blink is elicited by a puff of air to the eye; touching a hot object elicits a hand withdrawal response. Conditioning occurs when control of the elicited response is transferred to a previously neutral stimulus, the conditioned stimulus (CS), so that presentation of the CS (e.g., a tone, sight of the stove) elicits the response (eye blink, hand withdrawal). In a typical laboratory procedure, the CS comes about 500 ms before, and overlaps with, the UCS (puff of air). Both are terminated at the same time. After a number of CS–UCS pairings, the UCR (blink) originally elicited by the UCS would begin to occur at the onset of the CS, and prior to the UCS. (This statement is not meant to imply that the UCR and CR are identical responses. There are many instances in which the CR is very different, in fact the opposite of, the UCR. However, for the types of responses used in aging research, the CR and UCR are similar.)

Although most of the research on aging and classical conditioning has been done with animals, and while generalizing from animals to humans is risky, the results in both areas lead to similar conclusions. Older adults acquire classical conditioning responses more slowly than younger adults. While classical conditioning is sensitive to the effects of variables such as motivation and anxiety, which may be correlated with increasing age, it seems likely that differences in conditioning are not due to these factors.

Current approaches to classical conditioning and the more general category of associative learning characterize associative tasks as a class of tasks that can be viewed as a problem-solving situation faced by the organism. The problem is to determine, or learn about, the relationship between event A and outcome O. Does event A cause outcome O? Is A a reliable predictor of O? Specifically, is the probability of occurrence of O, given that A occurred, greater than the probability of occurrence of O, given that A did not occur? These accounts revolve around the CS–UCS connection. Of particular import is the information value of the CS. When the CS is a reliable predictor of the UCS, that is, the UCS always follows, but does not occur in the absence of, the CS, conditioning is rapid. Reducing the strength of either of those correlations results in poorer conditioning. In fact, if conditions are arranged so that the CS is a reliable predictor of no UCS (i.e., the CS is never followed by the UCS), subjects can learn to withhold the CR when the tone sounds. Current theories stress the idea that subjects are abstracting the information value of the CS or of the relative frequency of occurrence of stimulus events from their environment. Although the details of the theories are not relevant here, the implications for age differences are.

Researchers have been examining the parallels between associative learning (classical conditioning) and attribution of causality in humans. In one study, college students were presented 16 pairs consisting of a compound stimulus and allergic reaction outcome, and were asked to rate the likelihood that each element of the compound caused the allergic reaction. Thus, subjects might have been told that the patient ate shrimp and strawberries eight times, which resulted in eight allergic reactions, while after eight incidents of eating shrimp and peanuts, there were no allergic reactions. Across subjects, the correlation between the compound stimuli and the allergic reaction varied from 0 of 1. After all presentations, the subjects were asked to rate the degree to which each element of the compound stimulus (shrimp, strawberries, peanuts) caused the allergic reaction. Their ratings reflected the correlations, but of more interest was the fact that the results from the humans paralleled exactly those from analogous studies with pigeons. While there has been no aging research in this area, it has potential.

It is possible that the elderly have a decreased ability to learn the informational value of the CS or the nature of the CS-UCS contingency. According to one theory of classical conditioning, contextual stimuli become conditioned as part of the CS, thus reducing the strength of conditioning to the punctate CS, because the total associative strength is spread over all components of the CS. That is, the sights, sounds, and other external or internal stimuli in the situation may become conditioned as part of the CS. If the elderly are not as able to inhibit or suppress responses to these irrelevant stimuli, they will become conditioned as part of the CS, reducing its effectiveness as a predictor of the UCS, thus making learning more difficult.

Operant Conditioning

Responses in operant conditioning, like those in classical conditioning, are of relatively short duration and can be repeated many times without intervention by a researcher. Examples of these types of responses are presented in **Table 1**. Unlike classical conditioning, these responses are emitted by subjects rather than elicited by stimuli, and are followed by the critical stimulus event. The goal of the stimulus event is to alter one or more attributes of the response, such as the rate of emission, frequency, speed, or strength. Modification of the particular attribute may be accomplished by positively reinforcing (i.e., presenting a valued stimulus such as a candy bar, money, praise) when the desired attribute occurs, or negatively reinforcing (i.e., removing an aversive stimulus) when the response occurs. (Negative reinforcement might involve turning off an electric shock or noxious sound.) Another alternative might involve punishment of the response by taking away a desired stimulus (e.g., candy, privileges), or presenting an aversive stimulus (shock, insult, noise).

The limited amount of research involving the elderly has involved enhancing the speed with which tasks such as the digit-symbol substitution are performed, and indicates that both young and elderly benefit from reinforcement. There is some suggestion that the elderly may benefit more from reinforcement than the young. To the extent that basic research on operant conditioning has indicated that the role of reinforcement is a motivational or activational one (i.e., it affects performance rather than learning), these results have no clear implications.

Instrumental Learning

Instrumental learning is similar to operant conditioning in that the behavior of interest is emitted and the desired responses are followed by reinforcement or punishment in order to produce modifications. It differs in that the responses may be more complex or of longer duration, and they typically involve discrete trials. That is, the responses in instrumental learning can not easily be repeated without some external intervention. (In maze learning, for example, the animal can not repeat the maze until it is removed from the goal box and placed in the start box.) Results of animal research indicate that on simple tasks, age differences are minimal, but on complex tasks, young subjects are more proficient (take fewer trials to learn, make fewer errors) than older subjects. These age differences may be reduced, but not eliminated, by factors such as guidance through the maze (not allowing incorrect choices) and individual difference variables such as diet.

Partly because of its applied value, research employing more complex and real-world situations, such as learning to navigate in a new or strange environment, has been more frequent since the late 1980s. Studies using simulated walks (via slides) in novel environments produced the familiar age-related decrement in learning, and also revealed that the age difference was primarily due to a difference in learning route information. There was little age difference in extracting knowledge about landmarks on the trip. That is, elderly adults had more trouble than younger adults in learning the turns in a route, but were about as good at recognizing landmarks.

Verbal Tasks

Paired Associate Learning The classical associationist view that learning consists of the formation of individual stimulus–response (S–R) bonds or associations led to the use of paired associate learning (PAL) as a standard task. In a typical PAL task, subjects are presented a list of pairs of events (often words), with one arbitrarily designated as the stimulus and the second as the response. In the anticipation procedure, the stimulus is presented for some amount of time (e.g., 2 s), during which the subject is to try to produce the response. At the end of this anticipation interval, the response (or the S–R pair) is presented for some amount of time (e.g., 2 s) for study. One trial is competed when all pairs have been presented. After a brief interval a second trial begins, using the same procedure, but with the pairs, not the S-R units within the pair, in a different order. On the second and subsequent trials the subject must try to say the response aloud before it is shown. The entire process is repeated either for a fixed number of

trials or until a preset performance criterion is reached.

To provide a concrete example: suppose you have created a deck of 3×5 cards with a Spanish word on one side of each card and its German equivalent on the other side. As you flip through each card, you look at the Spanish word and try to say the German word out loud. Whether or not you say the correct word, you turn over the card and look at the German word. After going through the entire deck, you shuffle the cards and repeat the procedure.

It is clear from a great deal of research with college students that PAL is composed of a number of different component processes, each of which may play a role in various situations. Because at least some of these processes may be age sensitive, a brief review of them is relevant.

Several processes deal with the stimulus terms. Stimulus differentiation is the process of discriminating among the various S elements in the list. When using meaningful and distinctive items such as words, this process is less important than when the items are meaningless and have overlapping physical features. A related process, stimulus selection, may be invoked when items have overlapping features, but one of which allows each stimulus to be uniquely identified. For example, if the stimuli in a list were JSF, SFJ, FJS, KLW, LWK, WKL, the subject could select the first letter of each trigram as the effective stimulus and essentially ignore the remaining letters.

Similar processes are involved on the response side. Response learning refers to the acquisition of the responses, that is, being able to report the responses irrespective of the S–R pairing. Acquiring the responses may involve response integration, or making each response a unit, especially when it consists of a series of unrelated letters.

The final set of components refer to the associations between stimuli and responses. The S–R, or forward, association is the ability to produce R when presented S. This association may be strengthened by rote rehearsal or mediation. The R–S, or backward, association is the ability to produce S when presented with R. The R–S associations develop incidentally and often augment the S–R associations.

Results of cross-sectional and longitudinal studies indicate that increasing age leads to less proficient PAL. Elderly subjects attain a lower level of learning after a fixed number of trials and take more trials to reach the same criterion. Although early studies suffered from serious methodological problems, more recent studies correcting these problems have produced similar results. Analysis of the learning curves, that is, trial-by-trial performance data, of young and elderly indicates that both the intercept and the slope were affected by age. That is, not only do the elderly learn less on the first trial of PAL (which could be due to non-learning factors), but also their rate of learning (i.e., the number of additional items acquired on each trial) is lower than for younger subjects.

While it is clear that there are substantial age effects in PAL, the more important question concerns the possible locus of those effects. As in motor skill learning, in which cognitive aspects of the task are more age sensitive than other aspects, it may be that some of the component processes are more age sensitive than others.

There is ample evidence that at least part of the age-related decrement in PAL is due to the general slowing seen with age. Consistent with the idea that older adults are simply slower than younger adults is the finding that older adults make more omission than commission errors; they are more likely to not give a response than to give a wrong response, especially at faster presentation rates. Independent manipulation of the length of the study and anticipation intervals in PAL produces a significant age $\times$ anticipation interval interaction, but a nonsignificant age $\times$ study interval interaction. Short anticipation intervals are much more detrimental to elderly than to younger subjects, but there is a constant age difference in performance when the length of the study interval is varied. This pattern of results is consistent with the general slowing hypothesis. Producing a response should be a speed- and therefore an age-sensitive process. Processes involved in forming an association should be less dependent on timing, and thus should be less age sensitive. However, lack of an age $\times$ study interval interaction does not imply that younger and older adults do not differ in the processes or methods used to form associations.

Running parallel to the view that association learning is actually a problem-solving situation to which the subject brings a variety of methods and techniques is a similar view of PAL. In this view, the component processes that have been identified by classical research in PAL can be categorized according to the extent to which they tax the cognitive system. One would then predict that there would be larger age-related differences in effortful or cognitively demanding processes and smaller differences in more automatic processes. It is also likely that the type of material being learned would affect the size of the age differences.

Response learning is an important component in PAL, and research comparing conditions in which response learning is not required to conditions in which it is required greatly reduced, but did not eliminate, the age decrement in PAL. Also, increasing

the difficulty of the responses, and thus the cognitive effort required to learn them, by using nonsense syllable responses increases the age decrement. Related research in free recall learning indicates that age-related differences are most likely to occur when there is little environmental or situational support, or when self-initiated processing is required.

As in studying the role of response learning, one can look at the effect of age on association formation by comparing conditions requiring minimal associative learning with conditions requiring substantial associative learning. Results of studies using various methods and comparisons indicate that acquisition of the S–R association is an age-sensitive process. Interestingly, examination of the associative, or hook-up, stage may allow for differential predictions from the capacity and inhibition theories. Inhibition theory would predict that situations involving many competing responses (high-frequency words, multiple responses) should be more difficult to learn for elderly than for younger subjects, while a capacity theory would not necessarily make similar predictions.

There are two methods of forming S–R associations: rote rehearsal and mediation. While the associations can be learned by rote rehearsal, research indicates that it is a relatively ineffective method and a less preferred alternative, at least for college students. In one study, college students reported using mediators of various types on up to 75% of the pairs they studied. If younger and older adults rely differentially on rote rehearsal or mediational strategies, there will be age differences in PAL. Consistent with predictions from capacity theories, results of two early PAL studies indicated that older subjects were less likely to spontaneously use mediators of any sort, with 36% of the elderly and 68% of the younger subjects reporting mediator use. Also, young subjects reported using imaginal mediation more frequently than verbal, while elderly subjects reported just the opposite. Basic research on mediation indicates that in general, imaginal mediation is more effective than verbal mediation. Thus, part of the age difference in leaning S–R associations may be due to choice of mediational strategy.

Clearly, mediational strategies produce faster learning, and younger subjects are more likely than older subjects to engage in mediation. Researchers have studied the cause of this difference, either an inability to use mediators (mediational deficiency) or a production deficiency, simply not using mediators. Results of this research indicate that not only are the elderly less likely to spontaneously use mediators, but also instructions and training in the use of mediators does not eliminate the deficit. More recent research in the use of mediators indicates that elderly subjects do produce effective mediators during learning, but that they have more difficulty than younger subjects in retrieving those mediators at the time of test.

In summary, research indicates that age-related differences are found primarily in those processes that are effortful, require substantial amount of self-initiated processing, and provide minimal environmental support. There are small differences in stimulus selection and differentiation.

Transfer Transfer effects are found when learning one task either facilitates (positive transfer) or interferes with (negative transfer) learning the second task. Typically, the first list is an explicit list learned in the laboratory, although sometimes the first list is assumed to have been learned as part of the previous language experience. For example, learning the pair table-lamp in the lab might be made more difficult because of the strong association of table-chair that the subject had acquired outside the laboratory. Analysis of transfer in PAL has revealed two types of component processes, non-specific and specific.

Non-specific transfer effects refer to improvements in performance on a second task that are independent of the specific content of the tasks. The only two types that have been identified, warm-up and learning-to-learn, both produce positive transfer. Warm-up is getting used to the particular pacing and timing procedures of the task, and is generally eliminated as a factor after a few trials. Although there is no research on this factor as related to aging, the response slowing hypothesis would predict that it is most likely to become important as the rate of responding or the pacing of the task increases, with older adults requiring more warm-up time than younger adults.

The second factor, learning-to-learn (LTL), is defined as an improvement in performance on successive unrelated tasks. The amount of LTL can be substantial. One study with college students found a 2.75-fold increase in rate of learning as a function of extensive practice. These subjects learned 36 successive unrelated PAL lists (one list per day, every other day). Mean trials to criterion on the 10-item lists dropped from about 11 on the first list to 4 on the last list. No similar studies have been conducted with older adults, although some data do indicate that under self-pacing conditions the rate of improvement due to LTL is comparable for younger and older adults. However, results of other studies indicate that younger adults show a larger increase in LTL across lists than do older adults. Thus, no definitive conclusions are possible at this time.

Table 2 Transfer paradigms in paired-associate learning

Paradigm	*First list (A–B) pairs (stimulus response)*	*Second list pairs (stimulus response)*	*Processes involved and transfer effects*[a]	
A-B, C-D (control)	bug sleepy rug rural vat tranquil hat playful	cot gloomy kin insane gum dirty dam tearful	Warm-up Learning-to-learn	+ +
A-B, A-D	cot sleepy kin rural gum tranquil dam playful	cot gloomy kin insane gum dirty dam tearful	Warm-up Learning-to-learn S-R association	+ + −
A-B, A-Br	cot insane kin tearful gum gloomy dam dirty	cot gloomy kin insane gum dirty dam tearful	Warm-up Learning-to-learn S-R association R-S association	+ + −
A-B, A-B′	cot dingy kin crazy gum sullied dam crying	cot gloomy kin insane gum dirty dam tearful	Warm-up Learning-to-learn S-R association (depends on mediation)	+ + +/−
A-B, C-B	bug gloomy rug insane vat dirty hat tearful	cot gloomy kin insane gum dirty dam tearful	Warm-up Learning-to-learn R-S association	+ + −

[a] + indicates positive transfer; − indicates negative transfer.

The study of specific transfer effects evolved from the component analysis of PAL and research into the effects of various components. Examining these components requires two PAL lists with specific relations among the stimuli and responses. Some of the paradigms used in these investigations are summarized in **Table 2**.

The paradigm used to control for the effects of warm-up and LTL is the A-B, C-D paradigm, where A refers to the stimuli and B to the responses in the first list. The stimuli and responses in the second list (C-D) are unrelated to the first list. Note that because interest is in the learning of the second, or transfer, list as a function of the relationship between the two lists, all paradigms have a common second list. Variation in the relationship between the two lists is accomplished by changing the stimuli or responses on the first list. Thus, there are no possible confounds attributable to the different paradigms having different second lists; all groups learn the same second list.

Negative transfer results from several sources of incompatible or interfering forward associations, backward associations, or both acting together. Each of these sources can be examined by using the appropriate transfer paradigm. As can be seen in **Table 2**, forward associations are the primary source of interference in the A-B, A-D paradigm. The associations formed during A-B learning are elicited during A-D learning and interfere with learning the second list. Results of various studies indicate that younger and older adults show about the same amount of negative transfer in the A-D paradigm, a finding somewhat at odds with what is expected if the elderly have more trouble inhibiting irrelevant responses, that is, keeping them from intruding and interfering. Because this research was not designed to test the inhibition hypothesis, it may not have afforded an appropriate or sensitive test.

The role of the backward association in transfer is assessed through the A-B, C-B paradigm. To the extent that during C-B learning the B term elicits A, the first list stimulus, it will interfere with the acquisition of the new backward association. As mentioned earlier, older adults have weaker backward associations, that is, they evidence poorer R–S learning during acquisition of the A-B list. Thus, during C-B learning there should be less interference from the backward associations, and therefore less negative transfer for the older adults. However, methodological problems in those few studies using the C-B paradigm allow for no conclusions. The A-Br paradigm involves interference from both forward and backward associations, and thus might be expected to produce large amounts of negative transfer. Studies using this paradigm have found that both younger and older adults show large amounts of negative transfer, and that

older adults show substantially more negative transfer than younger adults. These results are consistent with both capacity and inhibition theories but do not provide analytical comparisons to be able to distinguish between the two.

As can be seen in **Table 2**, positive transfer over and above nonspecific transfer effects can be expected only in the A-B′ paradigm. In this paradigm, the second list responses are related (e.g., associatively, semantically, acoustically) to the first list responses. To the extent that the subjects can use the first list response as a mediator during second list learning, transfer should be positive. Inability to recognize or use the relationship would leave a nominal A-D, or negative transfer, paradigm. Thus, one might expect less positive transfer for older than for younger adults. Limited data bear out this prediction, at least as far as initial performance on the second list.

Summary and Comments

Three general conclusions can be drawn from the research on the effects of normal aging on learning. The most general conclusion might be 'You can teach an old dog new tricks; it just might take a little longer.' Normal aging produces decrements in almost all areas of learning, although the amount of the decrements will vary substantially across areas and individuals. Second, research psychologists have identified some of the age-sensitive component processes involved in various learning tasks, which should allow others to develop appropriate compensatory strategies. Finally, current theoretical accounts of age-related differences in learning offer additional insight into the aging process and to a better understanding of the learning process itself.

Research in many areas of cognitive psychology, including cognitive aging, which includes learning, has been utilizing functional neuroimaging technology such as magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), positron emission tomogrophy (PET), and event-related potentials (ERPs). The goal of many of these types of studies is to relate various cognitive tasks and processes to activity in specific brain areas. While research using these techniques clearly has great promise, the studies are yet too few and the results still give only correlational data. It is very likely that by the next revision of this article, the advances in this area will be substantial and significant.

See also: Cognitive-Behavioral Interventions; Conditioning; Decision Making and Everyday Problem Solving; Information Processing/Cognition; Life Expectancy; Memory; Motor Control.

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Leisure

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Glossary

Age, Cohort, and Period Effects – Age effects are attributable to biological, psychological, or social changes in an individual due to chronological aging. A decline in reaction time, for example, is an age effect. Cohort effects are due to differences in birth cohorts. Today's seniors are more active in sports, because they learned to play sports at an early age; their predecessors 50 years ago were too busy helping the family work the farm to learn sports on a large scale. Finally, period effects refer to the result of common experiences that different age groups experience together. An example would be the effect of living through 9/11 and the US war in Iraq, regardless of one's age today.

Busy Ethic – The value of being occupied with productive activity during retirement. The 'busy ethic' is the older retiree's functional equivalent of the 'Protestant work ethic.' A key distinction is the intentional use of the term productive. The busy ethic does not emphasize the kind of activity that often is referred to as spinning one's wheels; rather, it is illustrated by older individuals' calendars that are filled with bridge, golf, volunteering, shopping, looking after the grandchildren, and the like.

Elite and Mass Leisure – Elite leisure includes the kind of recreation that often has been called high brow and that includes activities involving classical music, reading serious literature, etc. By contrast, mass leisure refers to the kinds of free time activities that are commonly associated with the masses: sporting events, movies, and other low-brow activities.

Flow – The concept of engagement in any activity that requires such total concentration on the task at hand that the concept of time becomes meaningless. Such behavior represents an exact fit between the demands of the task and the ability of the individual to complete the task. Flow may be said to occur in any number of institutional contexts. Flow might be exemplified in the rarified atmosphere surrounding a scientist single-mindedly working out a particularly knotty mathematical problem, or in the relatively simpler challenge of a child intensely playing 'Chopsticks' all the way through without error for the first time.

Leisure – Commonly described as free time activity, as recreation or as play, leisure is most fruitfully seen as a complex experience across both time and activity dimensions. Historically it has ranged from conceptualizations like those in ancient Greece (a state of being exemplified by music and contemplation) to those of the early Puritans ('the devil's workshop'). Today, leisure is seen as a multidimensional construct that reflects individual perceptions in the context of societal values and norms.

Play – Usually applied to the child's unrestricted enjoyment of the moment, regardless of the nature of the activity, play generally is accepted to be activity for it own sake without extrinsic motivation. Play often is seen to emphasize exploration as well: exploration of one's environment and exploration of the self.

Recreation – The third member of the leisure/play/recreation triumvirate, recreation emphasizes the restorative nature of the activity that one pursues. Often seen as a way to re-energize the individual in preparation for returning to work, recreation also has been seen to have positive consequences for society as well as the individual.

Time Deepening – The three-dimensionalization of time. Particular characteristics of time deepening include multitasking, speeding up activities, substituting quicker activities for slower ones, and keeping precise schedules for organizing activities. Probably no technological innovation illustrates time deepening better than the personal computer: Often, for example, one has email, a word processor, an Internet search engine, a music download, and perhaps one or two other tasks running simultaneously, as one switches back and forth among them. This multitasking is facilitated by powerful memory that speeds up all the tasks performed on the computer. Finally, for those with dial-up Internet access or who are otherwise tied to time restrictions, scheduling one's work becomes critical.

Introduction

Leisure often has been characterized as nothing more than free time activity. In this sense, it has more in common with recreation than with play – two terms with which it often is confused. At the other extreme, leisure has been asserted to represent a state of being

to which one aspires. Here, leisure has more in common with the self-exploratory emphasis that many scholars attribute to play. Most social scientists, however, consider leisure to be something more complicated than simply free time but also less ambitious than the foundation for a lifelong philosophy of existence. If, as many have argued, leisure is a time-bound activity with a particular self-expressive purpose, then, for our purposes, it becomes important to try to describe the leisure of older individuals and how that leisure compares with their leisure when they were younger and with the leisure of younger cohorts. A major obstacle is the lack of operational definitions of leisure that extend beyond free time measures, so the latter will be used as a starting point. Finally, available evidence on leisure in one's later years can provide some insights into the current state of knowledge reflected in theories about social aging and how one ages successfully.

Conceptualizing Leisure

Leisure was best seen as play in early society, often inextricably mixed up with work activities in a life rhythm that was modulated by seasonal and daily time cycles. In this context, leisure's value was the celebration of work that had been completed. By the time society had become more segmented and a division of labor was forming – even before industrialization, but certainly reaching a peak in industrialized societies – leisure's dominant value was illustrated by its recreational role, which allowed one to become refreshed enough to go back to work. In today's technologically advanced societies, leisure's role is said to be evolving into a major life force with the value being placed on consumption, one aspect of which is illustrated by bumper stickers and T-shirts proclaiming "I shop," "Only one more shopping day till tomorrow," and "Ya gotta have plastic." Given such extremes of perspective, it is not surprising that many students coming into courses on leisure declaim: "Leisure is what I say it is." In an effort to avoid linguistic anarchy, we might consider the following definitional discussion of leisure.

Normative, Nominal, and Operational Definitions of Leisure

Definitions of leisure have run the historical gamut from leisure as a life force that encompasses one's whole being to the empirically friendly leisure that is free or leftover time. As DeGrazia has so ably pointed out, these different definitions of leisure have historical roots in different cultures' normative positions toward leisure. In ancient Greece, leisure was exalted as a state of being to which one aspired – if one was a free male citizen, that is. In the Puritan epoch following the Protestant Reformation, however, leisure became the devil's handmaiden, because free time came to symbolize a break from God and Godly works. As Weber has pointed out with respect to work, however, leisure is a social construct, a product of a society's values, beliefs, and norms; it is, therefore, neither inherently good nor inherently bad. Nash's leisure pyramid stretching from acts that harm society at the bottom to creative activities at the top illustrates the wide range of leisure's reach.

Discussing leisure in the context of aging requires that we take care not to proselytize on the basis of what we think leisure should be for older individuals – or for anyone else, of course. This creates a dilemma of sorts, however, since any definition of leisure that is not a synonym for whatever one does in free time runs the risk of appearing to be normatively based. Further complicating efforts to find useful definitions for leisure is the extent to which definitions of both play and recreation cross over into leisure's realm. Over 40 years ago, for example, the Neumeyers and Miller and Robinson suggested that recreation is behavior in which one engaged during one's leisure. Ten years later, Torbert and Rogers saw the degree of playfulness one exhibited in free time to be a measure of the amount of leisure one had in one's life. A parenthetical note worth mentioning at this point is that this encyclopedia contains no article on either play or recreation.

In order to convey leisure's meaning for contemporary social scientists, the following three nominal definitions differentiate leisure from free time and tend to set leisure apart from recreation and play. They are the International Group of Social Sciences of Leisure definition, which notes the placement of leisure activity as behavior in one's free time after one's normal obligations have been discharged, but which also emphasizes the range of such activities as possibly including simple rest or amusement, or adding to one's knowledge, enhancing ones skills, or contributing to the commonweal; Dumazedier's (1974: 71) interpretation of leisure as "time whose content is oriented towards self-fulfillment as an ultimate end"; and Kelly's (1996: 31) notion of leisure as "activity focused on the experience rather than instrumental outcomes."

If one turns toward the empirical world, definitions of leisure begin to defer to definitions of free time, a concept somewhat easier to manage than leisure. One particularly fruitful approach to finding an operationally useful definition of leisure is Parker's division of life space into time use and activity constraints. Time is used either for work (meaning paid

work) or non-work. Within non-work time are physiological needs such as eating and sleeping, non-work obligations related to family, household, etc., and what he calls leisure. Activity may reflect either constraint or freedom. For paid work, commuting to and from the job is required, but the activities in which one engages during the commute may be freely chosen to varying degrees. These include casual conversations, reading, and listening to music or books on tape. Leisure is even more evident in those work-related recreational activities that sometimes occur in the course of one's work: golf or tennis with clients, for example.

For activities wholly unrelated to paid work, the same dimension of constraint applies. For example, meeting physiological needs such as eating and sleeping is absolutely necessary, but constraint begins to be less obvious with regard to eating snacks and drinking alcohol with friends. The greatest freedom attends those activities we label as leisure: reading for pleasure, pursuing hobbies, playing sports, etc. The pendulum moves back toward greater constraint, however, when such activities are undertaken in a family context with one's children, for instance, and, of course, as part of one's work-related activities.

A second classification scheme is the relatively simpler one used in the Americans' Use of Time Project: paid work, family care, personal time, and free time. This scheme does provide finer breakdowns within each category that build in implicit, if not explicit, activity distinctions. For example, free time is broken down into educational, organizational, entertainment or social, recreational, and communicational activities. A third classification distinguishes primary, secondary, and tertiary activities. Multinational studies of time use as well as US trend data on time use beginning some 40 years ago have utilized the four-category classification scheme described previously, but then have taken the description of time use even further by detailing not only primary but also secondary and tertiary activities undertaken during the same time period. This acknowledgment of multitasking would appear to optimize the ability of researchers to determine whether a particular time period is being devoted to pure leisure or is a hybrid that contains elements of both leisure and non-leisure activity.

Why Do We 'Do' Leisure?

Various accounts have suggested leisure to be a social institution, a social domain, or a social dimension. While some have argued that for leisure to be an institution it must be relegated to industrial society and its aftermath, this appears to be too restrictive a focus. If we consider social institutions to be interweaving beliefs, values, and norms oriented to meet human needs, then the functions of play and play-like behavior in hunting and gathering and horticultural societies would appear to meet this definition. If, as suggested previously, our definition of leisure includes relative freedom and the potential for personal growth, then such early play – even in the context of mimicking war through early sport – should qualify as leisure.

Kelly, in the first edition of this encyclopedia, makes a slightly different argument about leisure's place in life by contrasting leisure as a domain, in which it "has parameters of time and space that are based in the social allocations of society," with leisure as a dimension, which he sees as "more of a theme that may be found in different forms anywhere and any time." This distinction suggests that the domain perspective is more sympathetic to the kinds of operational definitions of leisure described in the previous section, while the dimension focus emphasizes the overarching beliefs and values to be found in a wide variety of different activities, including paid work.

Leisure can also be treated in a multidimensional way. As a social institution, leisure does address basic human needs and desires and thus can serve the larger society as well. Leisure as a domain allows us to measure aspects of behavior in time and space that often are connected to what one normally thinks of as leisure but more often is described as free time activity. At the same time, leisure as a domain reminds us that leisure may not be limited by time and space, as demonstrated by the evidence of kidding around on the job, playing with one's children, and the kinds of activities often associated with older individuals. Such activities as volunteering for non-profit organizations embrace a number of work-related values but are nevertheless suffused with many leisure qualities like freedom, including the freedom to choose where one volunteers, the freedom to continue to volunteer or not, and the freedom to volunteer more or fewer hours. In addition, of course, the possibilities for personal growth embrace yet another important value of leisure (*see* Volunteer Activity by Older Adults).

Understanding Leisure in Later Life

Social Aging

The most relevant perspectives for understanding social aging as it relates to leisure would appear to be those arguments that deal directly with continuities

and discontinuities within aging individuals and how they relate to older people's well-being. The two that fought for primacy in gerontological thinking throughout the last quarter century – the much maligned disengagement theory and its antagonist activity theory – have receded somewhat to the background in favor of continuity theory and its modifiers, which emphasize adaptation by the aging individual. Disengagement theory's assumptions of a rational disconnecting from one's role relationships with co-workers and then family and friends has come under serious theoretical and empirical attack. While it is true that the theory may owe too much to biological reductionism and represent an apologia for the kinds of mistreatments society's representatives have bestowed on aging individuals in the not-too-distant past, nevertheless, there may be a kernel of truth to the idea that aging in some individuals can be seen through a disengagement lens.

Activity theory too has come under attack, primarily because of the lack of demonstrable causality in the many cross-sectional studies that purported to show a high level of activity correlating with a high level of well-being among older individuals. Based on studies employing longitudinal data, the discovery that older individuals who were never particularly socially active in their free time might find themselves to be unhappy at unwanted increases in their social participation levels indicates a more complex association between activity levels and well-being than originally believed. It is possible that the continuation of low levels of activity, as well as high ones, correlates positively with well-being – not high levels per se. Again, for some of the aging population, being active may very well be a key to successful aging. Such individuals illustrate Ekerdt's notion of the busy ethic, which is retirement's parallel to work's 'Puritan work ethic.'

At first glance, continuity theory and its amenders would appear to be the umbrella under which ideas connecting leisure activity to well-being could most efficiently be gathered. Retirement as a discontinuity of major proportions for many individuals, of course, complicates the fit between theory and data. Again, however, the busy ethic idea suggests an ideal way in which the problems produced by this discontinuity can be minimized.

Theoretical Connections between Obligations and Leisure

Even though many would argue that large segments of the population can have leisure without paid work (children, the unemployed, prisoners, stay-at-home moms and dads, and, of course, retired individuals), much thinking in the last half of the twentieth century about the reasons for engaging in various forms of leisure has dealt with paid work. If one were to substitute obligated time for paid work, then the vast majority of children and adults will be covered by the following discussion. Building on arguments about the relationship between paid work and leisure offered by others, one could conceptualize leisure's relationship to obligated activity (mostly paid work, but also school, family, and household obligations) in three general ways. While the arguments usually have been used to illustrate males working at paying jobs, the application of these ideas to older individuals and their obligations – females as well as males and whether or not they are in the labor force – would seem to be an appropriate use as well. Consider the following:

1. First, there may be a positive association between obligations and leisure. There are four ideas represented by this positive association. One suggests that work is so fulfilling that it spills over into one's free time. This phenomenon may be illustrated over the course of the life cycle by the individual whose teaching continues to be so fulfilling that she does not stop but rather uses what would be leisure time in retirement to keep doing what she wants: teach. A spouse may continue to be the primary cook in the household, because it is what he loves to do; he cooks not only for sustenance but also whenever he can for friends and family. In all such cases, one would expect Csikszentmihalyi's idea of flow to be operating – at least some of the time.

A second way in which paid work and leisure may be positively correlated is illustrated by the now-retired teacher whose interests extend from work to leisure and who, therefore, volunteers teaching religious school and reads to her grandchildren as well as to herself for pleasure. Her leisure mirrors her work interests. Again, the opportunities for flow would be increased in such cases. Both spillover and extension may be subsumed under activity and continuity theories and Ekerdt's notion of the busy ethic. Retirement, for many older individuals, means exchanging one set of behaviors and values regarding the productive use of time for a parallel set of behaviors and values.

Third, both one's world of obligations and one's leisure may be unfulfilling, and these realms may in fact feed off one another. The assembly line worker who is so damaged by the monotony of his job may find solace in getting drunk every night to forget. Similarly, when he retires, he may engage in equally damaging behaviors to fill up his free time: more

drinking, mindless television watching, fights with family and friends. The association between obligations and leisure is positive in the sense that negative behavior begets negative behavior. While there certainly is a sense of continuity here, it is not the kind that will produce well-being. Possibly, such individuals will begin to disengage as a way of dealing with their unhappiness; such disengagement may be intentional or unintentional. Finally, what Parker has called neutrality is the situation in which a person is engaged neither by work or other obligations nor by free time activities. These so-called gray people living their gray lives are emotionally disconnected from life, often going through the motions. Again, the association between obligations and leisure is positive in the sense that lack of engagement in one domain is mirrored by lack of engagement elsewhere. We would not expect such individuals in old age to change, unless, like their unhappy compatriots discussed previously, they begin to disengage.

All of the preceding cases would appear to support the basic arguments of gerontology's continuity theory.

2. There also may be a negative association between obligations and leisure. There are two ideas represented here. The first is the opposition of the domains in which one's obligations and leisure fall. Therefore, a businesswoman retires and spends her time learning to be a cabinet maker. She may already have worked with wood as a hobby during her preretirement years, in which case this also illustrates opposition between obligations and leisure. Another illustration is exemplified by the National Parks manager who has spent so many of his working hours outdoors but who relaxes by reading and, when he retires, by preparing to write about his experiences with the public. A second negative association is illustrated by the compensatory use of good leisure for bad obligations. This scenario probably is best captured by the (often apocryphal) example of the individual whose work world is filled with endless dreariness and boredom but who discovers peace and serenity through painting for pleasure, an activity carried into retirement. More likely are the individuals whose work is so alienating that they make career changes to reduce their alienation. Although some empirical evidence exists to show that this has occurred in the past, it may be that the new relationships between employers and employees engendered by downsizing and outsourcing will facilitate such apparently radical changes. If so, old age may arrive after one has made these life-changing decisions and, therefore, represents continuity from one's (recent) work life.

3. The connection between obligations and leisure may be non-existent. Such an argument assumes no strong commitment to one's obligations or leisure; at the same time, individuals described by this argument are not so disengaged from their obligations and free time that they fit the neutrality model described earlier. Instead, leisure takes on a recreational form for the office worker who likes her job well enough and who takes part of her 2-week vacation to travel and see new sights and the rest to putter in her garden. Her retirement years will be filled with a variety of activities, only some of which mirror her work life (e.g., reading) and familial responsibilities (e.g., sewing, quilting); other activities will include activities not related to her world of obligations (e.g., travel, bicycle riding). In historical terms, her leisure might be best understood as recreation in the Roman restorative sense or in the Utopian idea of divided time that did not prescribe what one did when one's obligations were finished. Such individuals may best illustrate continuity theory, because they either will be continuing or replacing with functional equivalent behaviors in which they had always engaged, or because they will have adapted to modifications in their environment in old age (*see* Retirement).

Leisure as Activity, Time, and Money

The analysis of empirical evidence on leisure in later years is fraught with a variety of problems. The first, of course, is the likely disconnect between nominal and operational definitions of leisure for all individuals – regardless of age group. The data that do exist generally measure leisure as a residual term. The three most prevalent measures of residual leisure speak to different dimensions of free time: activity pursued, time used, and money spent. Each has built in advantages and disadvantages, so together they may provide a reasonably accurate view of free time use among older individuals and, by extension, the beginning of an idea of older people's leisure.

The Pursuit of Leisure Activities

Activities pursued have been measured for a wide range of both mass and elite leisure activities. **Tables 1** and **2** present national data on attendance at selected leisure events by event and age group. In **Table 1**, the percentages across the top show that mass leisure activities such as movies (60%), sporting events (35%), and amusement parks (42%) attract the most people. The percentages at the bottom for the two oldest groups also reflect the popularity of movies, but the second-most attended venue for those 65+ is the art museum – an elite culture venue.

Comparison of percentages down each column reflects a clear linear decline in attendance from the

Table 1 US attendance at various leisure venues, 1992–2002

Age group	*Year*	*Percent attendance at least once in past year (%)*						
		Movies	*Sports events*	*Amusement parks*	*Jazz performance*	*Classical music performance*	*Non-musical plays*	*Art museum*
All	2002	60	35	42	11	12	12	27
	1992→2002	+1	−2	−8	0	−1	−2	0
18–24	2002	83	46	58	11	8	11	24
	1992→2002	+1	−5	−10	0	−2	−2	−5
25–34	2002	73	42	56	11	9	11	27
	1992→2002	−3	−5	−12	−3	−1	−1	−2
35–44	2002	68	42	53	13	11	13	27
	1992→2002	0	−1	−5	0	−3	−1	−3
45–54	2002	60	36	37	14	15	15	33
	1992→2002	+2	+1	−7	+3	−2	−2	+4
55–64	2002	47	26	27	9	16	14	28
	1992→2002	+7	+3	−3	+1	+1	−1	+3
65–74	2002	32	20	18	8	13	13	23
	1992→2002	−2	0	−11	+1	−1	0	+3
75+	2002	20	11	10	4	10	5	13
	1992→2002	+1	+4	−4	+2	+2	−2	+3

From US Statistical Abstracts for 1995 and 2004–2005.

Table 2 US participation in various leisure activities, 1992–2002

Age group	*Year*	*Participation at least once in past year (%)*					
		Exercise program	*Playing sports*	*Gardening*	*Dancing (not ballet)*	*Photography*	*Creative writing*
All	2002	55	30	47	4	12	7
	1992→2002	−5	−9	−8	−4	0	0
18–24	2002	61	49	21	6	13	13
	1992→2002	−6	−10	−10	−5	+2	−1
25–34	2002	60	40	41	5	12	8
	1992→2002	−7	−12	−10	−5	−3	+1
35–44	2002	60	37	52	4	14	7
	1992→2002	−2	−7	−5	−5	+1	−1
45–54	2002	59	29	55	4	12	7
	1992→2002	−3	−5	−9	−2	−1	0
55–64	2002	48	16	57	3	11	5
	1992→2002	−14	−5	−6	−3	+1	0
65–74	2002	47	14	57	4	8	4
	1992→2002	−9	−4	−6	−5	+1	−1
75+	2002	31	6	48	3	4	4
	1992→2002	−19	−1	−7	−2	+2	+2

From US Statistical Abstracts for 1995 and 2004–2005.

youngest age group to the oldest in the cases of movies (83 to 20%) and amusement parks (58 to 10%) and a somewhat more moderate decline for sporting events (46 to 11%). For the last four venues, the percentages actually tend to increase with age until about 45 to 54, and then drop slightly until 75+. In the cases of classical music performance and non-musical plays, in fact, the 65 to 74-year-olds have higher attendance rates than the 18 to 24-year-olds (musical plays, not shown, show the same pattern as non-musical plays).

The participation rate percentages in the top row of **Table 2** reflect a clear bias in favor of physical activity: exercising, gardening, and playing sports. While the rate at which they play sports drops significantly, the two oldest groups generally reflect the rest of the population; although, for those 65 and older, gardening is the most popular endeavor, followed by participating in an exercise program.

Comparison of percentages across age groups shows that exercise, sports playing, and creative writing rates are lower with increased age, and, in the latter two activities, the drops are precipitous. Dancing and photography show slightly higher levels of participation among the young, but the pattern is not as dramatic as in the first three activities. For gardening, however, rates increase as age increase, until 75+ – at which point there is a slight drop.

One problem with the 2002 data in **Tables 1** and **2**, of course, is the confusion of aging, cohort, and period effects. Are the age differences observed due to aging or to some combination of other factors? A partial answer comes from an examination of the percentage changes between 1992 and 2002 reported directly under each 2002 percentage in each of the first two tables. The 10-year time difference is not large enough to make too many generalizations, but a couple of comparisons are illustrative. For example, amusement park attendance shows a drop between 1992 and 2002 both in general and for each age group, suggesting some sort of period effect – possibly the substitute amusements afforded by computer games and the like. In the case of art museums, the relative similarity of percentages across age groups through age 74 tends to obscure the fact that in the 10 years between 1992 and 2002 the rates of attendance fell in the age groups under 45 but rose in the age groups 45 and older, even though the increases were not large. These different trends suggest possible cohort or aging changes at work, although the precise reason is not clear.

Data not presented here on specific sports activities show that for aerobic exercising and tennis, declines between 1992 and 2002 for the youngest age groups were in direct contrast to increases among those 65 and older. Here period effects may be interacting

with aging effects. Again, for each activity and each year, the participation rates among those 65 and older were lower than the rates for young and middle-aged adults, despite the contrasting trends.

The relationship between age and both leisure attendance and participation, therefore, is not so clear-cut. While some measures do appear to show a decline in activity with advancing age, others do not, and, for a few cases, the activity may very well be increasing with advancing age. Finally, cross-sectional data may be hiding patterns relating age to leisure activities that longitudinal or trend data can help uncover. What these and other similar data sources focusing on activity do not do, however, is provide a sense of how important these activities are to each individual. How comparable, for example, is the individual who went to one sporting event in the past year to someone who attends every home game of his or her professional sports teams? The data presented allow no way of distinguishing frequency of attendance or participation.

The Use of Leisure Time

Data on how time actually is used, usually gleaned from the personal diary method, has been shown by researchers in the United States and abroad to provide a wealth of information. Excellent sources of diary information are the Americans' Use of Time surveys that go back as far as 1965 but that unfortunately excluded anyone 65 and older until 1985. Nevertheless, some useful information can be gleaned from the 1985 and 1999 studies.

Using the residual definition of leisure as time not devoted to paid and household work, childcare, obtaining goods and services, and personal needs and care, the Americans' Use of Time investigators have divided free time into five categories, as shown in **Table 3**. Reading across at the top, one can see that free time takes up nearly 1 in every 4 h of each 24-h day (22.1%), and that nearly two-thirds of that free time is devoted to what the investigators call communication – a category that includes television watching, listening to the radio, reading, and conversing with others. Among those 65 and older, the proportion of time that is free increases to nearly one-third (30.8%), while the part of free time that is allocated to communication likewise increases to over three-quarters.

A comparison of age groups shows that for those under 65, the percentage of free time is more or less the same; only after the nominal retirement age of 65 is there an increase. By contrast, the percentage of free time devoted to communications activities steadily increases from youngest age to oldest. For the other free time categories, different patterns can be observed. Education, as expected, takes up a larger portion of younger people's time; for those over 35, very little time is devoted to education. Organizational activities, including volunteering and religious and political organizations – what Dumazedier calls semi-leisure – appear to be unrelated to age. Finally, recreation, which includes the kinds of activities in **Tables 1** and **2**, shows very few age differences, the only exception being a slight drop for the 65 and older group.

Table 3 US free time use by age group by time period, 1985–1999

Age group	*Year*	*Free time (percent of total time)*	*Free time allocated to (%)*				
			Educational activities	*Organizational activities*	*Entertainment/ social activities*	*Recreation*	*Communication*
All	1999 ($N=1151$)	22.1	3.6	4.9	14.9	13.8	62.8
	1985→1999	−0.6	−1.1	+0.4	−0.3	+2.2	−1.3
18–34	1999 ($N=330$)	21.1	12.1	4.2	20.8	13.3	49.6
	1985→1999	−0.8	+2.7	+1.3	+2.0	+2.6	−8.5
35–49	1999 ($N=366$)	18.6	0.7	5.4	16.6	15.8	61.7
	1985→1999	−0.6	−1.7	−0.6	+2.5	+4.5	−4.6
50–64	1999 ($N=216$)	21.5	0.6	4.4	10.3	14.3	70.2
	1985→1999	−1.5	−0.4	−1.5	−3.2	+2.4	+2.7
65+	1999 ($N=170$)	30.8	0.0	4.5	10.1	9.3	76.1
	1985→1999	+1.6	−0.4	−0.5	+0.9	−3.1	+3.1

From Americans' Use of Time Series Data Files for 1985 and 1998–9 (ICPSR numbers 9875 and 3191, respectively).

This last result underscores another significant weakness of the kinds of activity measures in **Tables 1** and **2**, if they are taken alone: attendance and participation rates appeared to be strongly negatively correlated with age in several instances, yet the diary data show that the amount of time devoted to these kinds of recreation activities is not nearly so different across age groups. Indeed, recent research shows that, while they may participate in fewer recreational activities than younger cohorts, middle-aged and older individuals are participating more frequently and for longer periods at a time.

If free time use differences between 1985 and 1999 are contrasted, age group differences appear to be patterned in three areas. Time spent on education increases for the 18 to 34 age group but declines for each of the others. Recreation time increases for all but the oldest age group, which shows a decline. Finally, those under 50 show a decline in communication, while those 50 and older show an increase. It's not clear whether these differences, small though they are, represent cohort or aging effects.

Two footnotes on the communication category. The first has to do with the single biggest user of communication time for all age groups: television viewing. Data not in **Table 3** show two important facts: The first is that television takes up two-thirds of all communication time and nearly half of all free time – regardless of age group. Second, over time, television viewing as a percent of all free time increases from 47.5 to 53.1% for those aged 65 and older but declines for each of the age groups under 65. Again, the cohort that is 65 and older by 1999 may be viewing more television because of their birth cohort's experiences with television, or there may be some other explanation. In any event, the increase in television viewing for older individuals calls into question the notion of an increasingly leisured senior population. The aged are a population with increasing free time perhaps, but does the television enhance a leisure lifestyle, or does it discourage self-growth and self-awareness? With the proliferation of cable television channels, the nature of the programs becomes a key to answering this question.

The second communication footnote deals with the emerging importance of cell phone usage. As an emergency standby, a means of social communicating with friends and family on the spur of the moment, and a source of experimentation with new technologies, the cell phone has insinuated itself into the workplace, school, home, and points in between. As of 2005, less than half of individuals 65 and older had cell phones, while over two-thirds of those under 65 had one. As younger cohorts age and older ones climb on to the cell phone bandwagon, its ubiquitous nature will render cell phones an important determinant of time use in general, and leisure use in particular, for older Americans.

Spending Money on Leisure

Probably least related to the notion of leisure is the expenditure of discretionary income on activities that take up one's free time. **Table 4** provides age comparisons with respect to expenditures on what is labeled entertainment, which overlaps many of the activities illustrated in **Tables 1–3**, reading, and education. Reading across the table, it is clear that entertainment takes up the bulk of the expenditures. All told, about $1 in $14 (7.3%) is spent on entertainment, reading, and education, and, of that dollar, two-thirds is spent on entertainment.

Reading down the table, one can see that the age group with the highest expenditure on entertainment is the 65 to 74 group. The group spending the highest percentage of discretionary monies on reading is the oldest. Not surprisingly, the group spending the highest percentage on education is the youngest. When all such discretionary expenditures are added together, it is the youngest that have the highest percentage, due primarily to their spending on education. After them, there is essentially no difference in percentage of discretionary expenditure on entertainment, reading, and education for the next five age groups; only among those 75 and older is there a measurable drop.

Change over time between 1984 and 2003 is relatively modest when it comes to spending on entertainment and the like. Noteworthy perhaps is the fact that entertainment expenditures rose slightly as a percentage for the older age groups but declined slightly for the younger. Reading declined very slightly for all, while education showed an increase for all but the two oldest groups. It's not clear what explains these results; but the only dramatic pattern is the education figure for the youngest age group. Not surprisingly, the youngest are spending a larger percentage of their discretionary expenditures on education, thus reflecting a contradiction to the continuity argument described previously – but at the beginning of one's adulthood, not the end.

One final point about leisure expenditures as they compare to leisure time used: leisure types of activities, defined on the basis of free time and its component categories of time use in **Table 3**, suggest that leisure is an important part of the life course at all stages. By contrast, money spent represents a small fraction of one's overall expenditures. There probably are several reasons for this, starting with the large proportion of time spent watching television and pursuing other activities in the communications

Table 4 US consumer expenditures for entertainment, education, and reading, 1984–2003

Age of householder	*Year*	*Average annual expenditure*	*Percent entertainment*	*Percent reading*	*Percent education*	*Percent entertainment plus reading plus education*
All units	2003	$40,817	5.0	0.3	1.9	7.3
	1984→2003		+0.2	−0.3	+0.5	+0.5
Under 25	2003	$22,396	4.2	0.2	6.7	11.1
	1984→2003		−0.6	−0.2	+2.4	+1.6
25–34	2003	$40,525	4.8	0.2	1.7	6.8
	1984→2003		−0.6	−0.4	+0.7	−0.2
35–44	2003	$47,175	5.3	0.2	1.5	7.1
	1984→2003		0.0	−0.3	+0.1	−0.2
45–54	2003	$50,101	4.8	0.3	2.7	7.9
	1984→2003		+0.4	−0.3	+1.0	+1.2
55–64	2003	$44,191	5.5	0.4	1.7	7.5
	1984→2003		+0.9	−0.2	+0.6	+1.3
65–74	2003	$33,629	6.0	0.4	0.5	7.0
	1984→2003		+2.2	−0.3	0.0	+1.9
75+	2003	$25,016	3.6	0.5	0.3	4.5
	1984→2003		+0.3	–0.2	–0.5	–0.4

From US Department of Labor.

category and ending with the relative inexpensiveness of television viewing, radio listening, book reading, conversing, and the like.

Leisure's Meaning for Aging

The arguments describing possible conceptual ties between leisure and obligations and the data on leisure activities, time, and spending over the life course have raised a number of questions. This last section addresses a central one: Why does leisure matter for the aging individual?

Leisure and Well-Being in Later Life

A review of the research on leisure and aging in the United States and elsewhere uncovers several cross-sectional studies, as well as some longitudinal research that confirms positive associations between leisure activities and various measures of well-being. Three themes emerge from the more than two dozen studies focusing on leisure in later life. First, leisure and well-being are positively associated, and this association probably is not spurious. As before, cross-sectional data show a positive correlation between various measures of leisure and subjective representations of well-being, including lowered stress and higher levels of self-esteem. In addition, however, longitudinal evidence in the United States, Sweden, and Germany has shown participation in leisure activities to have a beneficial effect on older individuals' well-being in a variety of ways. Specifically, leisure activities increase the psychological adjustment necessary after loss of spouse or functional impairment, reduce the risk of dementia (including Alzheimer's), and reduce the risk of mortality.

Second, the particular value of leisure appears to be directly related to the number of activities in which one engages as an older individual in some cases, but the picture is complicated. For one thing, engaging in a new activity that may be a functional equivalent for one that has been taken away or given up voluntarily seems to help older individuals' sense of well-being. For another, reducing the number of leisure activities while increasing one's energy devoted to the ones that remain has a beneficial effect for those older persons who are resource rich (but not for those with limited resources).

Finally, some of the research described previously has found important contextual differences by gender. For example, having a partner appears to enhance the leisure of older men but to decrease that of older women. In another instance, participating in leisure activities reduces the mortality risk of older men, but not older women, when health factors are controlled. These findings suggest several fruitful

areas of inquiry regarding leisure and aging. Researchers not only might examine gender as a context for examining leisure's place in aging, but also should treat other important background factors in a similar way. As Kelly has described, privations associated with being female, non-white, or poor have negative consequences for one's leisure and for one's well-being in later life. An important next major step should be a systematic separate examination of men and women, Whites and people of color, poor and non-poor individuals as they age in order to describe potentially different leisure patterns and to ascertain the ways in which leisure may or may not associate with well-being for each of these subpopulations.

The Busy Ethic, Flow, and Time Deepening

Earlier, downsizing and outsourcing were mentioned as potential new sources of discontinuity for today's work force. It will not be very long before large numbers of workers who have known only a work world in which these values exist will be retiring and heading into later life activities. Simultaneously, we have seen a cybernetic explosion this past decade that has put a personal computer and an Internet connection in over half the households in the United States and that has encouraged over half of those in their 60s and about one-quarter of those 70 and older to use a computer.

Both the world of paid work and the availability of personal computers and their technological offspring raise serious questions for those concerned with the role of leisure in later life. As succeeding cohorts enter the later stages of life, will the busy ethic paradigm continue to describe older individuals, or will there be an evolution of behavior in later life leisure of which we have seen only glimpses? The dominance of the new business model and the omnipresence of computer technology suggest that the busy ethic may continue to describe individuals in later life. Time deepening, including especially multitasking but also the speeding up of various behaviors, fits with the idea of multiple jobs over the course of one's work life and the computer as a mediator of simultaneous, speeded-up activities. In this respect, future generations of aged individuals may find the transition from the frenetic work world to the life of frenetic leisure a seamless one. Indeed, some of the research connecting leisure with well-being appears to support the idea that more is better.

By contrast, Csikszentmihalyi's notion of flow suggests the kind of more focused leisure that sacrifices quantity in favor of quality. The implied slowdown behind the idea of flow would appear to work directly against time deepening. True, both concepts stretch the meaning of time. Time deepening does it by stuffing as much activity into any given time slot, however, while flow makes time irrelevant, as the individual becomes caught up in the task. The evidence on older individuals engaging in fewer leisure activities but spending more time on leisure suggests that there is a functional alternative to the popular tendency to time deepen.

Successful Aging and Later Life Leisure

The recipe for aging well – living a long and happy life and dying after only a brief illness – is certainly consistent with the ideological definitions of leisure described at the beginning of this article. The evidence on leisure as discretionary time, however, raises the question as to precisely how aging individuals will engage in those activities that afford rest, amusement, and the potential for self-growth. For some of these older individuals, a life filled with a variety of discretionary activities may be the perfect recipe for successful aging. For others, however, a life devoted to a limited number of discretionary activities pursued in depth may make more sense.

Theoretically, recent evidence from longitudinal studies on the relationship between leisure and well-being appears to support activity theory. The mere number of leisure activities seems to have a direct, positive effect on well-being. At the same time, the evidence that resource-rich elders limit the scope of discretionary activities in their major leisure domain suggests support for another argument that is related to the basic ideas of continuity theory but that emphasizes adaptation to change. This argument comes from the SOC model, named for the three adaptation strategies of selection, optimization, and compensation. More research is needed to determine how well the model works in different cultural contexts for different populations of elders, but the ideas behind adaptation appear to be based on solid evidence.

In the near future, a mobile workforce, increased computerization, and time deepening will continue to encourage new experiences and communication across a wide range of personal networks that know no geographical boundaries. They also potentially will make it more difficult to focus one's attention on singular tasks that create tremendous self-satisfaction from being caught up in the moment and thus having rendered time irrelevant. Whether the two scenarios can co-exist peacefully will have a profound effect on the role that leisure plays in later life.

See also: Generational Differences: Age-Period-Cohort; Life Course; Retirement; Volunteer Activity by Older Adults; Work and Employment: Individual.

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Life Course

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Glossary

Cohort – The subpopulation of individuals who are born within the same time frame.

Cohort Effect – Historically specific circumstances that leave a distinct imprint on a particular cohort.

Life Course – A set of analytical perspectives designed to apprehend several key aspects of human development and age-related change. In biographical terms, it may refer to a sequence of roles and transitions embedded in a particular sociohistorical context, or as a trajectory of lived experiences. It may also refer to a set of social practices and ideas about how individuals should appropriately change as they move through time.

Life Cycle – The generational pattern of birth, growth, reproduction, and death, linking individual development to intergenerational dynamics and to the reproduction of the species.

Life Span – The maximum length of life of an organism.

Life Stage – A period of time that is part of a reliably recurring set of developmental stages in a species.

Introduction

The life course refers to a set of analytical perspectives designed to apprehend several key aspects of human development and age-related change. From its beginnings in the 1960s and early 1970s, the life course perspective has emphasized the impact of social structure on social change and on the organization of experience and individual opportunity, thus providing an important corrective to traditional assumptions of development and aging as universal, transhistorical, and transcultural processes. The life course perspective was first established as a field of study in the United States, where its primary focus, prominently articulated by Glen Elder, has examined the impact of early-life experience on subsequent outcomes. Several other theoretically distinct questions and issues have also been introduced within the domain of life course studies. For example, analysis of the historical shifts in the transition behavior of entire cohorts helped to define what Martin Kohli and others have termed the institutionalization of the life course, a process that can also be traced through the study of historical change in age norms and the meaning of age. Each of these perspectives and the attendant theoretical issues are reviewed here.

The Emergence of the Life Course as a Field of Study

The life course as a field of study is only a few decades old, yet it has increasingly been recognized as an area of considerable promise not only in the study of gerontology, but also in other substantive areas of social science inquiry such as family, education, work, and crime.

The beginnings of life course studies are generally traced to a series of independent lines of sociological scholarship in the 1960s in the United States. This work became visible beginning with Leonard Cain's

foundational paper on the life course, published in 1964. The following year, cohort analysis was introduced to the social and behavioral sciences by the classic articles of Ryder and Schaie. Cohort analysis contributed the recognition that social change produces differences in development, so that each historical period leaves a distinct imprint on the development and aging processes of its members. The social context of an actor's formative years is especially important, since it inevitably provides experiences and influences development in early-life that will reverberate across the adult years.

The discovery that individuals growing up in different historical conditions as successive cohorts age differently on many presumably stable characteristics such as age-related physical change and cognitive performance compelled the recognition that patterns of individual age-related change could not be reliably inferred from the longstanding practice of making cross-sectional age comparisons. It also gave a new importance and urgency to tracing individual lives through time, in order to gain an understanding of how the specific features of a historical period and social change create cohort effects by shaping early experience and subsequent life course outcomes.

Thus, the discovery of cohort analysis was a conceptual and analytic breakthrough that was codified in several fresh theoretical approaches developed across the social and behavioral sciences in the late 1960s and early 1970s. These included the life span psychology approach developed by Schaie, Baltes, and associates and in sociology the age stratification model introduced by Riley and associates. These developments also provided a fertile intellectual context for a flurry of studies identified as life course research, heralded by Glen Elder's classic study, *Children of the Great Depression*, first published in 1974 and printed in a second edition in 1999.

Meanings of Life Course and Related Concepts

It is generally useful to begin by defining terms and clarifying the scope of phenomena covered by a concept. This is perhaps especially so with a term as broad in scope and as widely used as that of life course. The term life course should first be distinguished from three similarly familiar, but not interchangeable terms: life cycle, life span, and life stage. These three terms are derived from the organismic model of the biological sciences, and, while allowing for varying degrees of environmental influences, they generally refer to the enduring and largely determined trajectories of growth and decline associated with development and aging. The life cycle refers to the generational pattern of birth, growth, reproduction, and death, linking individual development to intergenerational dynamics and to the reproduction of the species. Life span generally refers to the maximum length of life of an organism, which is regarded as a species-specific characteristic based on relatively fixed, biologically anchored processes of temporal change. Although it is a term that can refer to socially constructed as well as naturally occurring stages, life stage also derives from the organismic paradigm, more specifically, from the reliably recurring sequences of stage development that are observable in the life stages of many species of plant and animal life.

By contrast, the life course is anchored in biography and in history. These domains intersect the biological imperatives of the organism, but they are not reducible to it and are not determined by it. History and biography introduce distinctly human temporal dynamics that entail complexity, contingency, and change deriving from the diversity, flexibility, and culture-specific self-production of the human species. Thus, the life course implies human openness and social contingency. Life course scholars thus often speak of pathways, not predetermined life consequences, and of life history – the accumulation of events that occur over the lifetime of the individual.

Cohort, a term central to the logic of life course studies, refers to the subpopulation of individuals who enter a system within a specified time period. In studies of the life course, the system is usually society as a whole, and the defining entry event is birth (hence the term birth cohort). However, cohorts are not always defined by birth. They may also be defined by entry into a particular social system (e.g., school, military, work organization) or status (e.g., marriage, retirement).

A set of historically specific circumstances that leave a distinct imprint on a particular cohort is called a cohort effect. Cohort effects can take many forms. To take a familiar example, cohorts that enter adulthood during wartime are confronted with special, memorable, and, for many, fateful consequences. In this sense, cohort effects are closely related to what Elder has termed the life stage principle, which asserts that changed conditions have differential effects on people of different ages or stages. Such effects have generally been assumed to be most decisive for children, youth, and young adults, but they can affect trajectories throughout the life course and outcomes in later life. Other applications of the idea of cohort effects are based on the analysis of long-term trends. For example,

educational expansion has meant that, at least through the twentieth century, youth had far more education than their parents. Of course, this is not because the offspring were more talented or inherently motivated; it simply reflects the long-term societal trend toward increasing educational investments. Thus, the educational differentiation (and attendant differences in, e.g., cognitive test performance) between young and old is considered a cohort effect.

Cohort effects are often discussed in conjunction with two other categories of postulated causal factors: age effects and period effects. These are analytically distinct from, yet empirically confounded with, cohort effects. Age effects refer to the presumably transhistorical and enduring aspects of aging and development, such as puberty (of course, even the age of onset of fecundity has manifested a historical trend of change in late modern societies). The term period effect describes a historical event or period that has effects that cut across all cohorts. For example, large-scale disasters impact entire populations and markedly affect every age category. Whether or not the effect is entirely uniform across age or other individual characteristics is a secondary consideration in discussions of period effects.

It is important to distinguish between the concept of cohort and the concept of generation. Generation is a less temporally precise concept, implying position in relation to parents, sib or cousin groups, or other points of kin reference. Again, the intersection of individual lives with military institutions illustrates the relevance of the cohort–generation distinction. Consider the fate of young men in the United States during the Vietnam era. In some cases, cousins or even brothers belonging to the same generation but differing in birth years had dramatically different chances of being drafted for military service, based on cohort membership. For example, in 1969 the Vietnam draft applied only to young men born between 1944 and 1950. Therefore, those born after 1950 were not subject to being drafted in that year, but their older brothers were. Thus, members of the same generation encountered differential constraints and life chances based on cohort membership.

The term life course itself is not restricted to a singular meaning. It has been applied to respected lines of scholarship involving several types of individual and supra-individual phenomena. It has often been defined in biographical terms, as a sequence of roles and transitions embedded in a particular sociohistorical context, or as a trajectory of lived experiences that may be characterized by more or less continuity and punctuated by social transformations or individual life events. Such definitions seem to imply the tracing of individual-level patterns, and the concept is applied at the individual level. However, these characteristics can also be applied to entire cohorts and can be analyzed as features of culture as well.

Thus, Dannefer and Uhlenberg classified life course outcomes into three broad categories, representing different levels of analysis: the individual level, population level, and sociocultural or symbolic level. Individual-level analyses focus on individual-level outcomes; most frequently these are understood as having been influenced by the prior experiences of individuals that are carried forward through time in the form of, e.g., coping strategies, personality characteristics, or accumulated resources. Population-level analyses consider outcomes for collectivities, typically birth cohorts. These analyses consider the significance of social-structural factors encountered by populations as they move through the life course (such as age-graded or age-defined school experiences and Social Security or workplace pension programs). Finally, sociocultural or symbolic analyses define the life course not as a set of features of individual characteristics or change over time, but as a social construction – a symbolic representation of the movement of an individual through a sustained period of time. From this perspective, life course refers to a set of social practices and ideas about how individuals should appropriately change as they move through time. In other words, different cultural groups may have different publicly shared meanings and expectation for the course of human lives. Both the population and symbolic levels of analysis are especially important to the idea of the life course as a social institution, advanced by Martin Kohli. Examples of each of these three categories of life course outcomes are presented in the following section.

Principles of Life Course Analysis

In addition to the life stage principle described previously, Glen Elder proposed several other principles to consider while seeking to understand life course dynamics: These include (1) developmental aging, the idea that development and change are lifelong possibilities; (2) linked lives, the idea that each life is interdependent with others; (3) the principle of time and place, referring to sociohistorical specificity of experience; and (4) agency, which asserts the choice-making power of individuals. These principles enunciate important temporal and contextual dimensions that are essential for life course analysis. Nevertheless, others have offered extensions and amendments. For example, Hagestad and Dannefer argued that limiting the scope of interest in

linked lives to those with whom one has personal relationships can entail microfication – reducing a needed analysis of large-scale forces to the individual level. The lives of modern consumers are intimately linked to, e.g., the lives and work of farm and factory workers who live far away, and globalization has extended and strengthened these linkages. It has also been cautioned that a too-easy declaration of choicefulness must not be allowed to obscure the real and powerful constraints within which agency is exercised and choices are made.

Since the contingency of the life course is predicated on distinctive features of the human species, principles drawn from developmental biology and from symbolic interaction and social constructivism have also been identified as providing important foundational elements for life course theory. These principles emphasize the exceptional plasticity and adaptability of the human organism, the irreducible fact that individual identity and personhood are always formed in a specific time–space context, and the necessity of social interaction and cultural participation (e.g., language learning) to develop, sustain, and accomplish a life course. These principles thus provide a clear empirical basis for the importance of the life course not as reducible to developmental universals or constants that are sometimes emphasized by organismic approaches, but as contingent and specific. Human organisms require social interaction to become human beings, and thus are profoundly dependent on contextual dynamics from prenatality onward. Thus, the life course can never be reduced to normal or universal human patterns, only to social patterns. In every society, interaction is patterned and organized by broader features of social structure, including language. Such patterns are generally taken for granted and treated as natural within a given society. When viewed across societies, however, they reveal both the diverse potentials of the human life course and the active role of social forces in creating and sustaining each culture's definition of the life course.

Three Levels of Life Course Analysis

In this section, the three levels of life course analysis described previously, individual, collective, and symbolic, are discussed in some detail.

Life Course Outcomes at the Individual Level

The dominant mode of life course analysis is focused at the individual level, taking the individual as the unit of analysis. Such research typically proceeds by examining particular outcomes of interest at some particular point in the life course – usually midlife or later – and then identifying factors that may account for variation in each of those outcomes. Mental and physical health and socioeconomic status or achievement are among the more widely studied classes of outcomes. Research in this tradition has focused heavily on the role of early experience in shaping later outcomes, thus generating a time 1–time 2 (or $T_1 \ldots T_n$) design. Elder's *Children of the Great Depression*, described previously, is still the exemplar of this style of life course analysis. In the 1960s, Elder surveyed individuals who had participated in the Oakland Growth Study in the 1930s. These participants included individuals born 1920–1921 and their parents. In *Children of the Great Depression* and in scores of subsequent articles, Elder demonstrated that the effects of whether or not an individual was deprived during the Depression predict later outcomes. For example, among those who originated from the working class, those who were deprived during the Depression experienced significantly more behavior disorders than those who did not experience deprivation. The opposite is true for those whose parents were of the middle class.

A variant of this general logic is provided by the studies of John Clausen, who also employed the basic logic of the time 1–time 2 design, and who also used data from the Berkeley and Oakland studies began in the late 1920s and early 1930s. Unlike Elder and others, however, Clausen did not build historical events and change systematically into his framework and analysis. Rather, he argued for the importance of a psychological factor – a personality characteristic that he termed planful competence, which is formed by adolescence, as a significant predictor of later successes.

These studies used context as an explanatory variable in the sense that specific features of early-life experience were hypothesized to be predictors of health or status in later life. In some cases, the same logic has been fruitfully applied in examining the development of lives from midlife onward. In further analysis of the Oakland data, for example, Elder and Liker found that adult women's circumstances during the Depression had a predictive effect on their mental health decades later. In this case, class and hardship interacted. The best outcomes were achieved by middle-class women who experienced deprivation during the Great Depression. Working-class women and middle-class women who did not experience the challenges of deprivation did not fare as well. Based on these findings, they proposed that mastery of early-life struggles enhances adaptive capabilities in later life. Scrutiny of this research tradition has yielded some discussion of how the concept of time is

used in the life course literature. One relevant issue concerns the relation of time with another central life course term, context. As several observers have noted, the relevance of contextual factors as operative variables here are limited to their role at or prior to the earlier (time 1) point in the life course upon which time 2 outcomes are predicted. The role of context after time 1 is silenced. For this reason, Dannefer and Uhlenberg term this style of analysis personological. Since this term can be taken to imply that only individual-level factors are at play and since early-life context is typically part of the predictive model, use of this term generated some controversy.

Especially recently, some life course studies focused on individual-level outcomes have examined the importance of contemporaneous social-structural variables in addition to those from the past. This is important, because it provides a basis for assessing the relative importance of early-life factors versus temporally proximate ones, and it also elaborates the nature of the causal mechanisms through which early experience operates. Two examples of this approach are provided by the recent work of Sampson and Laub and of Crosnoe and Elder. Sampson and Laub accomplished this in their re-examination of a classic data set from a longitudinal study of juvenile delinquency and adult crime. In addition to recognizing the importance of early-life context in delinquency and the continuity between childhood/adolescence and adult criminal behavior, their framework assumes that social circumstances encountered in adulthood are also significant in understanding persistence of antisocial behavior, desistance from criminal behavior, and adult-onset criminality. In this study, 500 White male delinquents and 500 nondelinquent matched controls were interviewed first between the ages of 10 and 17 and then 15 years later, when they were between ages 25 and 32. Consistent with other research and with the premises of the life course perspective, Sampson and Laub found that early experience had a predictive effect, but to an important degree it was mediated by other adult experiences. The effect of adult social bonds was substantial and was identical for the two groups when earlier delinquent careers were controlled. Specifically, weak social bonds related to employment and marital attachment were strongly related to crime and deviance among both delinquents and controls, net of earlier influences, demonstrating the importance of current context to individual outcomes.

Crosnoe and Elder also included contemporaneous variables in their study of how early family experiences relate to adjustment and functioning later in life in an analysis of the Terman sample of talented children. They found strong effects upon current health and well-being of early-life antecedents, but they also found that these early experiences largely operate through current objective circumstances.

This kind of analysis is important in helping to specify the mechanisms through which the effects of early-life experience on later outcomes are accomplished. These studies appear to support the importance of adult circumstances as having an independent causal effect on adult outcomes. This is an issue that has implications for policy as well as for research and theory. If positive change in circumstances in adulthood makes no difference in the patterns already established by one's life history, interventions to improve circumstances may have little return in health or lifestyle improvements. On the other hand, if improved objective conditions are found to improve adult well-being, it lends support to arguments that a social return may be realized from improving the circumstances of adults. Like most studies, those described here are rather specialized, but they do suggest hypotheses to be tested on more representative samples.

Life Course Outcomes at the Population Level

Population-level analyses are concerned with collective outcomes. Collective outcomes are properties of the cohort that cannot be reduced to the individual level. One obvious feature of any population (or, in this case, cohort) is its distribution on a given characteristic – the size and shape of the distribution of its members around the mean or other measures of central tendency. Concern with the distribution relates to issues of diversity and inequality among cohort members. Viewed in temporal perspective, it also relates to the degree of age-graded conformity or homogeneity with which cohort members complete key life transitions.

Conformity in life transitions has been assessed by a number of analysts, using demographic measures such as spread or the interquartile range. For a given transition (such as entry to adulthood or the transition to retirement), spread refers to the length of time it takes for a specified proportion of the population to go through a particular transition. Similarly, the interquartile range is based on a record of the age at which each cohort member undergoes the transition in question. It reports the number of years it takes for the middle half of the cohort to complete the transition (the 26th to the 75th percentiles). Applying this measure to cohorts of young men born in the United States between 1907 and 1952, Hogan found a steady trend toward a reduction in the interquartile range applied to the transition to adulthood. Reduction in the interquartile range means a reduction in

the age variability of transition behavior and, correspondingly, an increasing level of age-graded conformity in successive cohorts across the first half of the twentieth century. As time passed, the age-graded behavior of young men became increasingly similar, as each successive cohort completed the transition in fewer and fewer years. Over the second half of the twentieth century, the transition to retirement appeared to reflect a similar trend toward greater age homogeneity.

These dramatic historical shifts toward greater levels of homogeneity and age-graded transition behavior have been given two kinds of interpretations, one based at the individual level and one more sociological. Some have suggested, paradoxically, that greater conformity in transition behavior reflects a higher degree of individual prosperity and hence economic freedom, which allowed young men to marry earlier. Such an interpretation implies a natural or at least culturally preferred age for marrying. Others have seen this historical trend as an indication of the increasing institutionalization of the life course. This term requires a conceptualization of the life course as a social institution, a notion that has been extensively discussed by Martin Kohli and others. Both of these interpretations point toward the development of age norms and the increasingly precise expectations for age-graded behavior that they imply. The related concepts of age norms and the institutionalized life course are discussed in the next section.

Premised on observations about the extraordinary diversity and inequality that are observed in older age strata of the population over the life course, some analysts have focused on the question of how intracohort variability changes over the life course of a cohort, giving rise to the concept of trajectories of variability. While this question is in principle applicable to many characteristics, most such analyses have relied on income data, for several reasons. Population and other macro-level data on income are relatively accessible, and income is regarded as an index of resources that is likely related to health and to other forms of resources. Analyses of trajectories of inequality for income show a remarkably robust pattern of steadily increasing inequality within each cohort as its members age. Most of these analyses have been conducted in the United States, and whether the same pattern exists across societies or only in certain societies remains to be clarified.

Two major explanations of this phenomenon have been advanced, which may be termed accentuation and cumulative advantage/disadvantage. Accentuation begins with features of the individual, such as personality and decisive early events, which may shape the individual's habits and aspirations that then become accentuated as he or she moves through the life course. In contrast, cumulative advantage/disadvantage emphasizes the operation of stratification processes within social systems, examining how they organize the opportunity structures that individuals experience while they are growing up and throughout the life course. The stratification of opportunity has been studied in schools and in the dynamics of the labor market and the workplace, but it also has roots in an individual's family of origin.

While few would dispute the relevance of both kinds of dynamics, how much causal force to attribute to individual-level accentuation and psychosocial development processes on the one hand, and to sociogenic cumulative advantage/disadvantage and opportunity structure processes on the other, remains a matter of interpretation and debate. Whatever the interpretation, the matter of resource inequalities is important for theory and also for social policy, since a strong and enduring relationship exists between resources and health. A number of significant recent analyses of health and resources have placed great emphasis on the role of social stratification processes and outcomes in accounting for health differences. This includes research in the sociology of health, epidemiology, and related areas and is well represented in the work of Michael Marmot and others working in these areas. Applying this general proposition to life course trajectories, researchers such as Mirowsky, Ross and Wu have shown that the health of individuals also tends to diverge over time along social class lines.

Life Course As a Feature of Social Organization and Culture

The life course is also embedded in social arrangements and practices and in their legitimation by ideas, or sets of ideas, that have force and legitimacy in a given social system. Its focus is not the empirical life course of actual individuals, but the life course as it is variously inscribed in social institutions, in social policies, and in popular culture. Of course, the characterizations of the life course in social institutions and in popular culture are not independent of each other.

The nature and significance of the life course as a symbolic construction can be readily illustrated by considering the institutionalization and force of public retirement pension schemes (such as Social Security in the United States and *Gesetzliche Rentenversicherung* [legal pension insurance fund] in Germany). These programs have complex political and cultural histories, but what is common to all of

them is the notion that there is an age-qualified time of life when people should be freed from work. This is a matter of social policy and practice, and it is also a symbolic construction – an idea – that is part of each society's cultural system and that has become an important part of what Berger and Luckmann termed the world-taken-for-granted experienced by the members of that society. Thus, it becomes an idea that influences many aspects of the lives of individuals: everyday behavior, life planning, relationships, etc. It also contributes to the formation of a definition of what is normal in a specific segment of the life course, the segment that is known as old age.

The analyses of historians, demographers, and other social analysts have clearly demonstrated that the public establishment of an age-graded life stage of retirement is just one manifestation of the general historical process of what Martin Kohli and others have termed the institutionalization of the life course. This process, which tended to follow the industrial revolution and the expansion of government bureaucracies, in part reflects an increasing reliance on age as a criterion of social organization. In the United States and elsewhere, this practice first developed with the expansion of public schooling. Universal public education was soon followed by the implementation of age grading as a general educational practice. More recently, focus by educational and health professions and by the popular media on normal developmental issues, whether in very early childhood or in turning 30, the midlife crisis, or the empty nest stage, have encouraged the continuing development of what historian Howard Chudacoff has called age consciousness and, with it, age norms. These developments entail an increasing reliance on age as an index of individual characteristics and appropriate social relationships and more generally as a basis for determining status, aspirations, and behavior.

The institutionalization of the life course refers to more than the organization of individual lives by social institutions such as school and retirement. It also has produced a bureaucratically organized, age-graded normative organization of society. This age-stratified social organization entails age segregation – the separation of individuals into age-homogeneous groups that are relatively insulated from each other. Age segregation is experienced as a normal part of everyday life and is sanctioned and reinforced by widespread institutional arrangements from the school years onward. Thus, it is experienced as a taken-for-granted aspect of social life, supported by the notions of normal life course development supplied by the institutionalization of the life course.

The idea that the nineteenth and twentieth centuries comprised a historical moment of institutionalization in modern bureaucratic states has more recently been called into question. The contemporary trends of postindustrialism, globalization, and so-called postmodern cultural developments have suggested the hypothesis that the life course is now being deinstitutionalized, as diversity in the transition to adulthood and in patterns of marriage and parenting have emerged, and as changes in the economy and in corporate organizational structures have led to announcements of the demise of the traditional one-career imperative. Current efforts at pension reform in the United States and elsewhere can be taken as further evidence of destandardization and increasing variability in life course processes. Others argue that, despite these developments, the policies and structures that support the components of the institutionalized life course (e.g., pension policies that support retirement, school and school-to-work programs, and family support programs) remain popular and strongly entrenched, especially in Europe. The economic challenges related to the globalization of production combined with the demographic challenges of graying populations will ensure the relevance of questions of the extent and shape of life course institutionalization for some time to come.

Change/Stability and Structure/Agency: Enduring Problems of Life Course Analysis

Like any lively field of research, the study of the life course has been characterized by a number of ongoing debates and unresolved conceptual and methodological problems. Some problems concern the design of research, especially with issues surrounding longitudinal data analysis. Until recently, few longitudinal data resources were available, but with the recognition of the need to follow individuals over time, that situation has changed. Still, the tasks of matching research questions to appropriate data and the analysis of longitudinal data raise thorny questions for life course researchers.

Beyond these methodological issues, some important issues of design and interpretation confront researchers working in the life course tradition. Two such issues entail the tensions between change and stability and structure and agency. Each of these is briefly discussed in the following sections.

Change/Stability

As noted previously, the reality of social change has been central to life course analysis from the beginning. The recognition that changing social conditions produce different patterns of aging in midlife and later

life and that unique events can play a decisive role in shaping subsequent life outcomes was central to the establishment and expansion of the life course perspective in the behavioral and social sciences. Thus, change and history are familiar and prominently featured ideas in much of the writing on the life course.

At the same time, it is important to be aware that the significance of social forces in shaping life course outcomes in no way depends on the degree of change that is occurring. Under conditions of stability as well as change, individual selves, individual personhood, and the individual life course are constituted in interaction with a social and cultural environment that supplies relevance structures that provide a context for values, interests, and aspirations to be formed and opportunity structures that regulate individual life chances. Change does nothing to create such pervasive social forces; it only makes them more visible. Under conditions of stable and strongly legitimated social systems, such constantly recurring, multilevel interactions and life course dynamics tend to be thought of as normal. This psychosocial process, sometimes called naturalization, can lead to a misspecification – attributing causal phenomena that originate in the realm of social forces to individual volition or temperament.

Structure/Agency

From the beginning, the idea that social structure, change, and other dimensions of context both direct and constrain the direction of individual lives has been central to the life course perspective. At the same time, life course analysts have frequently emphasized individual choice making, action or agency, as one important factor or node of analysis of life course outcomes. This contrast has set up a tension between structure (which is sometimes mistakenly associated with a fear of social determinism) and agency (sometimes erroneously assumed to be synonymous with free will). In the life course literature, as elsewhere, terms such as choice and agency on the one hand, and context and structure on the other, have been used to mean quite a range of different things and are often used without clear definition. Marshall identified at least eight distinct ways that the term agency has been used in the life course literature and provided a critical analysis of their assumptions.

An important theme in several recent analyses of agency is that the common assumption that structure and action are inherently opposed concepts is inappropriate. The interactionist traditions of social theory, as articulated in the writings of Weber or as synthesized in Berger and Luckmann's modern classic, *The Social Construction of Reality,* make clear that human agency is always operative in social life, true even in situations of extreme constraint. At the same time, social-structural processes are also always operative, often at levels that are so pervasive and fundamental that they are barely discernible. For example, it is through social processes that the linguistic, cultural, and political contexts of everyday life are defined. These contexts inform intentional human action and provide the field in which individual agency can express itself.

The debates of stability/change and structure/agency resonate far beyond the domain of life course studies. Indeed, they are fundamental to the social and behavioral sciences. Yet the multileveled, dynamic, and temporally extended subject matter of the life course ensures that researchers in the life course tradition will be confronted with them. It is not yet clear whether or not life course studies can contribute to advancing a more general understanding of problems such as these.

Summary

The life course emerged as a field of study in the 1960s and since then has offered promise of a means to understanding how history and social structure interact with individual experience to produce commonalities and patterned diversity in human experience. Beginning with the logic of cohort differences and cohort analysis, conceptual and analytical breakthroughs have brought a new appreciation of the important roles of history and context in the development and aging of individuals and entire populations. More recently, the roles of systematic social-structural processes and individual processes in producing intracohort differentiation and stratification have been elaborated. Research on the life course can be considered to occur at three levels of analysis: the individual level, the population level, and the symbolic/cultural level. At each, both individual-level (e.g., psychological) and social (e.g., structural and interactional) explanations have been proposed to account for many kinds of life course outcomes. While recent advances in theory and methodology have enhanced the study of the life course, problems remain in life course analysis, including the tensions between change and stability and agency and structure. A challenge for current and future scholars of the life course will be to determine how to best approach these issues.

See also: Age Stratification; History of Gerontology; Life Span Theory; Longitudinal Studies; Narrative and Aging;

Self-Regulation, Health, and Behavior; Theories of Aging: Social.

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Life Events

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Glossary

Intracategory Variability – The differences that may exist between any two reports of the same event.

Life Event – Any change in lifestyle routine that prompts a need for readjustment. Four major domains of life events among the elderly include social losses, illness events, changes in social roles, and shifts in the patterns of everyday life events.

Introduction

Studies of stress and adaptation began the journey into the investigation of life events at the start of the twentieth century when Walter Cannon wrote of his observations of the bodily changes that followed a stressor. Adolf Meyer introduced the life chart into medical offices, linking life events to physical and psychological outcomes in the mid-1900s. Others

also explored the relation between stressful life events and the physiological, emotional, and behavioral responses that ensued, but did so anecdotally. The development of standardized measures in this domain began in the 1960s with the introduction of the Schedule of Recent Experiences (SRE) by Thomas Holmes and Richard Rahe. Over the past 50 years, there have been many advances in theory and measurement. Indeed, life events research continues to be a dynamic and exciting field.

There is no universally accepted definition of a life event, but the definition proposed by Holmes and Rahe is used most frequently. They defined a life event as any change in lifestyle routine that prompts a need for readjustment. Within that definition, there are two aspects that must be addressed: what constitutes an event, and what constitutes change? Life events range from relatively small daily events, such as being stuck in traffic, to major sociopolitical events, such as a major flood or a declaration of war. Change may range from small disturbances, such as altering the path one takes to work that day, to major changes, such as moving in with a romantic partner and the impact of that change on one's coping strategies. The wide spectrum of possible events and consequences raises a difficult issue for researchers.

Life event research has primarily examined the consequences of events by charting their impact on life course trajectories and health outcomes. A longstanding focus has been the relation between negative life events and decreases in quality of life, as measured by symptoms such as physical decline and psychopathology. Consistent links have been drawn between negative social interactions and depression, anxiety, and mortality among older adults. However, recently research has begun to focus on desirable events such as positive social interactions with friends and family and personal achievements such as competing successfully for an award and their impacts on health and well-being.

Why should we study life events among the elderly? Do older adults have different types of stressful experiences than younger adults, and do they struggle with resolving problems of adjustment that follow the occurrence of these events to the same degree? Older adults typically report fewer change-producing events on standard life event inventories than do their young or middle-aged counterparts. However, biases in measurement and recall may be leading culprits of differences in reports rather than overwhelming stability in the lives of the elderly. Common events among the elderly do not include those developmental tasks of early and mid-adult life such as childbirth or beginning a new job, which are included on standard inventories. For elders, retirement, change in work responsibilities, and bereavement, illness, and episodic pain are more likely, but not all of the events associated with developmental challenges of older adult life are found on standard inventories. Earlier reviews of the literature have identified four major domains of life events among the elderly: social losses, illness events, changes in social roles, and shifts in the patterns of everyday life events.

This article focuses on inventories for the assessment of life events for older adults, with special attention given to advances in theory and measurement made over the past 50 years. It discusses these advances in four critical areas of life events research: dimensions of life events, method and measurement issues, consequences of life events, and future directions. The goal is to inform the reader of existing research and methodological issues in assessment and provide a framework to guide future applications in theory, research, and interventions with older adults.

Dimensions of Life Events

There are several dimensions of life events addressed in the literature (**Table 1**) that are critical to understanding and assessing them.

Change

The magnitude of the life event, or the extent to which it causes a change in daily activities and prompts a need for readjustment, is a fundamental property of life events. Early inventories scaled events according to the degree of readjustment required by using magnitude estimation procedures. In the original SRE by Holmes and Rahe, they assigned Life Change Units (LCUs) that were developed by a panel of outside raters to each of the 43 events on their inventory. The sum of all LCUs was then taken as an indicator of overall stress. Another approach is to predefine events by setting a cut-off score at which an event will qualify as either major or minor. The use of weights to scale the stressfulness of events has not proven to be effective at improving the score's correlation with other measures of change. There is

Table 1 Dimensions of life events

Major	Minor
Desirable	Undesirable
Low threat	High threat
Independent	Dependent
Congruent with developmental and social contexts	Incongruent with developmental and social contexts
Recurring events	New events

ongoing debate on how to improve the assessment of change in the inventories. One recommendation is to expand assessment to obtain information about some of the following dimensions.

Desirability

Whether the event is a desirable experience, undesirable experience, or both, is perhaps the most fundamental attribute of an event. There has been a longstanding emphasis on negative life events and their impact on functioning and health, showing consistent links between negative life events and physical illness. Undesirable (negative) events have also been shown to be related to higher rates of depression, anxiety, and somatic complaints. However, recent research examining desirable events, which also may facilitate change, suggests that they may also play a distinct and important role. Studies indicate that positive events are common among older adults and may offset the effects of negative life events, protecting against feelings of anhedonia and loneliness. Positive events, although shown to be significant predictors of well-being, have not been thoroughly addressed in the literature. Positive associations have been found between desirable events and quality of life and psychological well-being. However, desirable events play a lesser role in predicting psychological distress, suggesting that desirable and undesirable events should be assessed separately rather than as opposite ends of a single continuum. To understand the complex interactions in an individual's daily life, a complete matrix of both desirable and undesirable events must be examined.

Ratings of desirability of an event can be obtained by self-report or by consensus scores established by objective raters. Some researchers have also obtained profiles of the individual's plans and goals independent of event ratings and determined the extent to which that event interferes with those goals. Therefore, undesirable events would be those that interfere with the achievement of or advancement toward goals.

Contextual Threat

Brown and Harris introduced the dimension of contextual threat in their measure, the Life Events and Difficulties Schedule (LEDS). Contextual threat takes into account the circumstances surrounding a life event, such as other recent events and life conditions that provide a backdrop for the current event of interest. For example, the loss of a spouse or partner may be very different when the loss was unexpected, left a person with little to no other social support, and generated significant financial strains. In the LEDS approach, the degree of threat is rated by consensus of a group of persons not involved in the interview on a four-point scale from marked to little or no threat. The ratings are based on the event and extensive background information on the event, but not on the respondent's subjective reports of threat, therefore reducing an important source of potential bias in life event assessments.

Control

Another important dimension is the controllability of the event. Research has shown that uncontrollable events are related to greater levels of distress than controllable events. Methods have been developed to assess whether an event is fateful, that is, occurs independently of the behavior of the person. Uncontrollable events have been linked to greater psychological distress than controllable events, which tend to be more desirable. Among older adults, death and illness of family members are generally considered the most stressful fateful life events. In theory, injury and illness are also fateful; however, those illnesses and ensuing treatment can also influence outcomes directly, rather than through their life stress effects.

Some research studies suggest that seemingly fateful events are not necessarily random; rather, individuals may play a role in creating the interactions in their lives. In individuals, the experience of positive and negative events has been shown to be rather stable over time and event categories (e.g., financial, interpersonal relationships), and individuals experiencing negative interactions with one set of relationships tend to experience negative interactions in other relationships as well (e.g., with family, friends, children). Indeed, individual characteristics, such as neuroticism and affective reactivity, may influence the likelihood of positive and negative events and the magnitude of the readjustment required. The use of daily process paradigms presents an exciting opportunity to better tease apart the issues of cause, effect, and independence between individual characteristics and life events.

Event Congruence

Some events are likely to occur and may even be expected given the person's stage in life. Other events may be highly unusual. The degree to which an event may be thought to fit, or be congruent, is an important dimension in life event research, particularly among the elderly. Across the life span, various events are more or less common given societal and developmental norms. For example, the death of a

spouse is much more likely in late life than in the first few decades of life. Events that are incongruent in the given developmental period are perceived as more stressful for the individual.

Recurring Events

Similarly, given an individual's experiences over the life course, there are few types of events an older adult will experience that he or she has never faced before. Older adults may be better able to navigate the adaptational demands from those events they have faced in the past. However, other dimensions would likely influence this effect, such as the magnitude or desirability of the life event that is recurring. The impact of new versus recurring events on outcomes has yet to be thoroughly assessed.

Cumulative Effects

Other research has examined whether there are cumulative effects; that is, are individuals who experience more life events at greater risk for poorer physical and mental health outcomes? Some research has shown that as the total number of events increases, so do levels of major depression. The extent to which the cumulative events are capable of overwhelming the individual's capacity may be the driving force behind these correlations. More rigorous research is needed to examine the long-term trajectories of individual adaptation following experiences of clusters of life stress events. There are two major theories driving research on stress and adaptation among older adults. First, the theory of inoculation proposes that direct and cross-tolerance will build up one's immunity and further one's ability to tolerate other stressors. Through experience, therefore, one is better able to handle stresses in the future. Alternatively, the opposite reaction to stress may occur. That is, when individuals experience stress they then have heightened vulnerability to subsequent stressors. There has been support in the literature for both models. The thoroughness of recovery from the life stress and the timing of subsequent stressors are likely to define whether greater or less vulnerability to future stressors results. Further research needs to be done that more clearly discriminates between these different patterns of vulnerability and invulnerability as a consequence of life events.

Method and Measurement Issues

Many life event inventories have been developed over the past 50 years since the SRE was introduced by Holmes and Rahe. These inventories vary in their comprehensiveness. Some inventories reference only major events; others assess only daily events. Some inventories have been developed to assess events that are most relevant to specific populations, special circumstances, or age groups. For example, special inventories have been developed for veterans of war, refugees, victims of assault, children, and adolescents, among others. **Table 2** lists commonly used life event measures. Rather than enumerating a comprehensive list, it identifies frequently used scales that are representative of the range of approaches used to assess life events. There have been several life event measures developed for use with older adults, such as the Research Inventory of Major and Small Life Events for Older Adults, the Pleasant and Unpleasant Event Schedules for the Elderly, and the Louisville Older Persons Event Schedule.

In the development and evaluation of life event inventories, there are several criteria that may enhance the reliability and validity of event measures. First, in concordance with the definition of a life event, an event ought to be observable, have a discrete beginning, and signify a change in ongoing activities. Second, inventories must be able to tease apart other components of life stress so that spurious associations are not identified. Life event items should not include dimensions that are related to the presence of a disorder or influenced by a person's mood state at the time of evaluation. For example, there are considerable confounds in assessing illness events such that it may be difficult to distinguish properly between health events that are signs of the illness and those that are clearly independent of the disorder. Likewise, current depressive mood may influence self-ratings of desirability and stressfulness of an event. Well-constructed life event inventories minimize such confounds.

Issues of redundancy and comprehensiveness are also important to consider. There are often several items in an inventory that overlap and assess the same experience. Items can be linked, as in 'car broke down' and 'had an automobile repair expense,' or they may describe a pattern of events that nearly always co-occur, such as 'marital infidelity' and 'marital conflict.' It is preferable for inventories to count each event only once. On the other hand, there are limits to the degree of comprehensiveness of any measure. Comprehensiveness can be improved by using open-ended probing for additional events not included on the investigator's list. Moreover, most event inventories thoroughly cover undesirable events but inquire about relatively few desirable events. Older adults generally report considerably more desirable events than undesirable events; adequate measurement of desirable events among this

Table 2 Commonly used inventories of life events

Measure	*Format*	*Dimensions and/or subscales*	*Reference*
Schedule of Recent Experiences	Checklist	43 items ranging from major to minor events	Holmes TH and Rahe RH (1967) The Social Readjustment Rating Scale. *Journal of Psychosomatic Research* 11: 213–218.
Life Events and Difficulties Schedule	Interview	Eight domains (e.g., changes in role, personal health, other's health, goal fulfillment)	Brown GW and Harris TO (1989) *Life Events and Illness*. New York: Guilford.
Research Inventory of Major and Small Life Events for Older Adults	Checklist	Thirteen life domains (e.g., work, social, financial, crime, transportation)	Zautra AJ and Guarnaccia CA (1988) Research inventory of major and small life events for older adults. Paper presented at 41st annual meeting of the Gerontological Society of America, San Francisco, CA.
Structured event probe and narrative rating (SEPARTE)	Interview	Life events, ongoing situations, and personal dispositions	Dohrenwend BP, Raphel KG, Schwartz S, Stueve A, and Skodol AE (1993) The structured event probe and narrative rating (SEPARTE) for measuring stressful life events. In: Goldberger L and Bresnitz S (eds.) *Handbook of Stress: Theoretical and Clinical Aspects,* 2nd edn., pp.174–199. New York: Free Press.
Life History Calendar	Interview	Residence, marriage, children, education, work, other events	Caspi A, et al. (1996) The life calendar: a research and clinical assessment method for collecting retrospective event-history data. *International Journal of Methods in Psychiatric Research* 6: 101–114.
Pleasant and Unpleasant Event Schedules for the Elderly	Checklist	Frequency, impact score (enjoyable or aversive), mean cross-product (amount enjoyable/aversive over previous month)	Teri L and Lewisohn P (1982) Modification of the pleasant and unpleasant events schedules for use with the elderly. *Journal of Consulting and Clinical Psychology* 50: 444–445.
Checklist of Life Events	Checklist	Positive life events Negative life events	Krause N (1986) Stress and sex differences in depressive symptoms among older adults. *Journal of Gerontology* 41: 1–39.
Geriatric Social Readjustment Rating Scale	Checklist	35 items ranging from major to minor	Amster LE and Krauss HH (1974) The relationship between life crisis and mental deterioration in old age. *International Journal of Aging and Human Development* 5: 51–55.
Louisville Older Person Event Scale	Checklist with follow-up probes	56 items ranging from major to minor	Murrell SA, Norris FH, and Hutchins GM (1984) Distribution and desirability of life events in older adults: population and policy implications. *Journal of Community Psychology* 12: 301–311.
The Elders Life Stress Inventory	Checklist	Egocentric Nonegocentric	Aldwin CM (1990) The Elders Life Stress Inventory: Egocentric and Nonegocentric Stress. In: Stephens MAP, Crowther JH, Hobfoll SE, and Tennenbaum DL (eds.) *Stress and Coping in Later-Life Families,* pp. 49–69. New York: Hemisphere Publishing.
The Geriatric Adverse Life Events Scale	Checklist with follow-up probes	Six domains (e.g., financial/work difficulties, interpersonal conflicts, disruption in living situation)	Devanand DP, Kim MK, Paykina N, and Sackeim HA (2002) Adverse life events in elderly patients with major depression or dysthymic disorder and in healthy-control subjects. *American Journal of Geriatric Psychiatry* 10(3): 265–274.

Modified from Zautra AJ, Affleck G, and Tennen H (1994) Assessing life events among older adults. In: Lawton MP and Teresi JA (eds.) *Annual Review of Gerontology and Geriatrics*, pp. 324–352. New York: Springer.

population may be particularly salient. The absence of desirable events may be particularly diagnostic of difficulties that would not be detected through probes of undesirable experiences alone.

In general, there have been two major approaches to inquiry of life events: self-administered checklists and semistructured interviews. Checklists provide an economical approach, whereas interviews provide greater detail and accuracy at the cost of efficiency and resources. The majority of studies have used self-administered checklists to obtain information on life events. Checklists have the marked advantage of being economical, requiring fewer resources for training, administration, and scoring. In addition, this format has been shown to increase response rates to more sensitive topics, such as abortion or sexual assault. However, reliability has been shown to be a significant limitation of the checklist approach. Over brief periods of time, checklists are reasonably reliable; however, significant issues arise when tests are administered a mere 2 weeks apart. Attempts to counterbalance these deficits have been to provide more detailed definitions of the event or to follow up positive responses with additional open-ended questions.

The second major approach entails more detailed interview formats in response to the major shortcomings of the checklist format. In the interview approach, individuals are asked a series of open-ended questions or follow-up probes to get greater detail about the events and the dimensions surrounding them. Individuals may be asked about when the event happened, circumstances surrounding the event, details of the event itself, and their reactions to the event. The advantages of this approach include greater test–retest reliability, reduction in the biases induced by current mood states, and greater ability to predict outcomes. The significant improvements in reliability and validity, however, come at the cost of significant amounts of time spent training interviewers as well as collecting and scoring each interview.

Intracategory variability appears to be a major factor that has been driving inconsistencies in the study of life events. Intracategory variability refers to the differences that may exist between any two reports of the same event. For example, the loss of a friend may be a very major or very minor event depending upon whether the person was an integral member of the person's social network. Little systematic research has been done to examine the differences in affirmative responses across individuals or even across the same person's repeated experiences of an event; however, the existing research suggests that intracategory variability is alarmingly high. That is, people endorsing the same item are often reporting very disparate experiences. This variability can be minimized by using an interview approach, or by obtaining subject ratings of stressfulness and/or the undesirability of the event.

Another issue in measurement is the reliability of event recall. Inventories differ in the time periods they assess. Some inventories assess lifetime or cumulative events, whereas others assess events that have occurred within a specified time period, often within the past 6 months or year. The time period of assessment brings up several critical issues regarding the reliability of life event measures. Inventories that attempt to capture events across the life span typically provide a calendar or use other techniques to prompt recall and help individuals to better establish time sequences. In general, there appears to be relatively good test–retest reliability when measured over brief periods of time. However, there seem to be significant limitations in long-term recall, biases in reporting (e.g., fluctuations in mood or public opinion that influence report responses), and problems with reporting an event in different categories with repeated measurement.

In the assessment of life events among older adults, problems with long-term recall may be particularly apparent, as individuals may be asked to recall events that happened several decades ago. With that in mind, long-term recall studies have focused on major life events given that recall of minor life events is not viable. Studies on cumulative negative life events have shown that older adults report fewer total negative events. This may be due to cohort effects, but it may also be due to limitations and biases in recall. Cognitive processes may be at work to significantly impair the accuracy of the retrospective recall of life events. A phenomenon called the fading affect bias suggests that the affect associated with negative events fades more quickly than the affect associated with positive events. This is a clear limitation of retrospective recall that has not been adequately resolved.

Two alternative approaches that are better able to accommodate the causal limitations and challenges in measurement are the use of longitudinal analyses and daily diary studies. Both of these approaches provide the opportunity to document and assess actual changes, rather than retrospective perceived changes, surrounding life events. In addition, the use of hierarchical linear modeling provides the opportunity to examine differences within and between individuals in their responses to life events. That is, are there differences across individuals or circumstances under which certain individuals will experience positive or negative consequences of life events? Longitudinal analyses allow researchers to examine

life trajectories and other critical aspects of this research such as the impact of cumulative life events. Daily diary studies provide a method of assessing the nuances of everyday experiences, examining in detail both stability and change, typically over a 30- to 60-day period. Diary studies minimize the problems associated with recall and enhance understanding of the immediate impact of life events within the context of everyday life. The advancement of these methods and statistical analyses has introduced important opportunities to further develop life event research.

Consequences of Life Events

The assessment of life events has been consistently linked to physical and mental health outcomes. In particular, negative life events have been linked to depression, anxiety disorders, speed of recovery from illness, and onset of medical disorders. Positive events have small but consistent effects, predicting enhanced well-being and higher quality of life.

Existing life event research on the elderly has focused on life events and rates of depression. Research shows that negative life events have a modest but significant relationship with depression. In particular, the degree of threat to one's identity is a better predictor of rates of depression than the magnitude of total stress associated with the event. Research has shown multiple pathways between stress and depression, in which depression both precedes and follows life events. Researchers in this domain have examined the role of attachment, appraisals, and cognitions in the generation and response to life events across individuals.

Research assessing the link between life events and depression suggests variable outcomes depending on whether an individual has experienced a prior episode of depression. The kindling hypothesis suggests that prior episodes of depression lower the threshold at which major life events impact health and well-being. This hypothesis posits that as the number of previous episodes increases, a person's vulnerability to stressful events also increases. Several studies have supported this hypothesis, whereas with previous episodes of depression the risk of a depressive episode following a major life event is significantly greater. However, research has shown that when the number of previous episodes is greater than nine, there is little additional impact from subsequent episodes.

Lab and daily diary studies have begun to distinguish some of the short-term effects of events as well as the mechanisms that underlie those outcomes. In particular, this research has focused on physiological responses to traumatic and other major, negative life events. Studies have looked at changes in the hypothalamic–pituitary–adrenocortical (HPA) axis, such as levels of cortisol, immune system dysregulation, and changes in structure and activation in the brain, via brain imaging techniques. Research in this domain has flourished over the last decade and advancements continue to be made. However, the physiological response to stress is incredibly complex, involving a number of hormones and systems with bidirectional influences. Therefore, research to date has produced several inconsistent findings, and current understanding of these mechanisms is limited.

One finding that has been relatively consistent is a link between stress and autoimmune dysfunction. Research has shown faster disease progression of chronic illnesses among individuals reporting greater levels of stress in their daily lives. Given autoimmune and other physical health concerns among the elderly, this is a particularly important field of research that continues to evolve. In addition, it appears that the type of event, either chronic or acute, has a differential impact on the immune system's ability to ward off illnesses. Sheldon Cohen and colleagues found that individuals experiencing chronic stressors (>1 month) are more susceptible to developing a cold than healthy adults experiencing acute stressful life events (<1 month).

In similar lab paradigms, individual differences in cortisol reactivity and antibody response influence susceptibility to developing upper respiratory infections. For example, research has found that individuals who have a greater cortisol reaction to lab-induced stress and who experience higher numbers of stressful life events have higher rates of upper respiratory infections than individuals with high cortisol reactions experiencing fewer stressful life events and higher rates than individuals with lower cortisol reactions regardless of the number of life events they experience. That means an individual's natural physiological response to stress may be an important factor that influences the likelihood of ill-health outcomes in the face of negative life events. Similarly, individual differences in antibody response to infection, basal levels and reactivity of other hormones (e.g., prolactin), and other physical health factors may influence individual differences in the impact of life events on physical health. Much more is needed to understand this complex web of interactions.

The few studies of long-term effects of life events have primarily focused on the effects generated by childhood trauma and traumatic events over the course of the lifetime. Although assessment strategies to date for long-term effects have been compromised

by reliance on retrospective accounts, this body of research has consistently found that exposure to trauma predicts vulnerability to later psychological and physical health problems. For example, studies of World War II and Holocaust survivors have shown that they have higher rates of post-traumatic stress disorder (PTSD) and other anxiety disorders than others their age who did not directly experience those traumatic events. Many theories suggest that trauma endured during childhood may be particularly detrimental, altering developmental processes and neural pathways and laying the basis for physiological responses to stress throughout the lifetime. This is a rapidly growing area of research, but much more must be done before a better understanding can be reached of the complex interactions of stress, trauma, and life events across a lifetime in predicting physical and psychological health.

Women have been shown to experience greater emotional responses to negative life events, with rates of PTSD two times higher in women exposed to trauma than in men. Theories abound about why there are gender differences in rates of psychological distress, ranging from predispositions to role-related stress. A well-designed study by Kessler and McLeod found that the tendency of women to be emotionally invested in the lives of those around them was a considerable source of higher psychological distress.

Among older adults, the relation between life events and cognitive decline is particularly salient. Cognitive decline is a natural part of the aging process; therefore, causal links between life events and cognitive impairment are particularly problematic. Not only do these changes influence recall limitations and biases, but changes in cognitive functioning may also be an outcome in life event research among the elderly. Cognitive impairment associated with PTSD has been well documented, showing problems with immediate and recent recall among diagnosed individuals. The magnitude, degree of threat, and duration associated with the event are probably critical factors influencing short- and long-term effects on impairment. In fact, some research has shown that acute stressors may enhance cognitive functioning, whereas chronic stressors may be detrimental.

The impact of life events may be moderated by (depend on) an individual's social resources, such as marital status, social connectedness with friends and family, and/or other ties with religious or community organizations. That is, the impact of life events on outcomes will be different depending on whether an individual has high or low levels of those factors. Other moderators may include personal characteristics, such as self-esteem, perceptions of control and mastery, self-identity, emotional complexity, and an individual's ability to regulate his or her emotions. Research has shown that individual coping and attributional styles may also interact with various types of life events to produce different effects across individuals. For example, individuals who have an internal locus of control (believe their own actions determine outcomes) may have a more difficult time coping with an uncontrollable negative life event than individuals with an external locus of control (believe their own behavior does not matter much). Unfortunately, a complete review of potential moderators that impact the effects of life events on outcomes is outside the scope of this article.

Future Directions

Although the field has come a long way over the past 50 years, many questions remain. In assessing life events among older adults, the literature is relatively sparse in comparison to research with other age groups. In addition, the numerous life event inventories that have been developed for children and adolescents outnumber the tailored inventories for assessing the elderly. It is critically important that research uses inventories that tap the types of events encountered by this distinct population. As the elderly become a much larger percentage of the US population, research within this field must be enhanced.

As previously mentioned, the interaction between individual characteristics and the experience of life events is an exciting and potentially fruitful area of research. The use of daily process paradigms to examine daily fluctuations and interactions between life events and individual behavior and outcomes is increasingly commonplace. The ability of this research to examine individual experiences within the context of daily life and the individual's psychosocial world has been significantly enhanced with statistical advances in recent years. This research advances the understanding of why, when, and for whom life events have the greatest impact.

In addition, more research is required to fill in the biopsychosocial model and provide a better understanding of how cognitive, behavioral, emotional, and physiological responses to events are all interconnected. For example, lab and diary methods have begun to assess the physiological substrates thought to be related to daily life events and individual responses to stress. However, research examining sympathetic response, the HPA axis and cortisol secretion, and autoimmune markers has been mixed, varying across samples and procedures. This is a particularly important domain among the elderly, given autoimmune and physical vulnerabilities experienced

within this population. Additional research in this domain will help fill in the gaps in understanding that currently exist.

Questions remain as to how life events intersect with developmental processes. Several theories suggest that the goals and emotional processing of older adults are markedly different than those of their younger counterparts. The types of events that were threatening at the age of 20 may no longer seem important. As older adults experience changes in their daily roles, purposes, and goals, they also experience and are influenced by positive and negative life events in different ways. Recent applications of dynamic systems theory to developmental psychology may provide tools to better understand the interactions between developmental changes, life events, and health outcomes.

There should be an increased focus on resilience in the study of older adults' reactions to life events. Resilience research seeks to explain why and how individuals are able to recover from stressful situations. Several fields are currently examining the growth-producing effects of events, such as posttraumatic growth. This literature is plagued with the issues in measurement and study design that were highlighted previously. Thoughtful and thorough prospective research designs and measures are imperative for advances in the understanding of how people recover.

The inquiry into events continues to evolve and holds considerable promise in the study of the lives of older adults. It is hoped that this article may serve to prompt new research on life events that will help to advance the current understanding of many challenges that have come to define the lives of older adults.

See also: Depression; Life Satisfaction.

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Life Expectancy

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Glossary

Active Life Expectancy – The period of time that one can expect to live free of functional impairment.

Life Expectancy – The average number of years a person in a population could expect to live after age x.

Morbidity Compression – The rate of improvement in life expectancy relative to active life expectancy.

Introduction

Life expectancy is the average number of years a person in a population could expect to live after age x. It is the life table parameter most commonly used to compare the survival experience of populations. The age most often selected to make comparisons is 0.0 (i.e., birth), although, for many substantive and

policy analyses, other ages such as 65+ and 85+ are more relevant and may be used (e.g., for determining person-years of Medicare and Social Security benefit entitlement). To calculate life expectancy at age x (e_x), age-specific mortality and population counts are needed to determine the age-specific mortality rates (i.e., the q_x) and survival probabilities (l_x) used in life table computations. Life expectancy is determined by multiplying the sequence of the probabilities of survival at each age to determine the proportion of a population expected to survive to age x. The number of persons expected to be alive in each single year of age category after age x is summed to determine the total number of years left to be lived after the index age (L_x). The total number of person-years to be lived after age x divided by the expected number of survivors to that age yields the life expectancy at age x.

Common Forms of Life Expectancy Calculations

Life tables may be calculated in abridged (e.g., rates calculated for every 5 years of age) or complete (rates calculated for single years of age) forms. Life expectancy is a realized biological trait of a given birth cohort (all persons born in a given year) – though most often life table computational strategies are used to combine data from the survival experience of multiple birth cohorts observed at different ages at a point in time. Such cross-sectional or period life tables reflect the experience of the synthetic cohort constructed from the period-specific experience of multiple birth cohorts. Thus, such statistics do not describe the experience of a real population unless there are no differences in age-specific mortality rates between the cohorts observed for the period of interest.

Cohort life tables are calculated by following a population born in a given year to extinction. Thus, true cohort life tables, and life expectation calculations for current human populations, are rare due to the scarcity of high-quality survival and death data for a cohort followed 100 or more years from birth to extinction. Cohort life tables, survival and hazard modeling, and life expectancy calculations are often applied to animal and insect experimental populations. In those much shorter-lived populations, it is easier to gather accurate data by direct observation to calculate cohort life expectancy statistics.

An alternate type of life table used in studying human mortality to late ages involves forming a synthetic population by summing deaths occurring in a given calendar year back over age from the oldest observed age at death to birth (age 0). Life table age-specific mortality rates are formed from the synthetic population counts for each age and the observed number of deaths in the age interval. Such extinct-cohort life tables may be used to examine mortality at very late ages, since this does not require accurate population counts at late ages (only accurate age-specific counts of death made for the calendar year observed). A confounder in extinct-cohort calculations is that the number of deaths at each age comes from cohorts initially different in size due to cohort differences in fertility. An age-specific growth factor can be used to adjust for initial cohort size differences.

The life table calculations used to determine life expectancy are generally assumed to be nonparametric in form; i.e., no assumptions are made about the distribution of deaths across age category boundaries. This is feasible when life tables are calculated for large national populations where age is reported with little systematic error. Often, however, populations are not large enough for age-specific mortality rates to have negligible uncertainty, and, in many populations, age is not precisely reported at extreme ages (e.g., ages 95+). In these cases, biologically based models (e.g., the Gompertz or Weibull hazard functions) of age changes in mortality risk may be used to smooth rate estimates over higher age categories. For example, in the life tables calculated by Social Security Actuaries, a Gompertz-type hazard function is used to calculate mortality rates at ages over 95. This strategy, however, involves imposing assumptions about how mortality changes at advanced ages. Since many studies question the biological validity of the Gompertz hazard function above age 85 (possibly due to mortality selection of a heterogeneous population at younger ages), this procedure is problematic. The National Center for Health Statistics (NCHS) uses Medicare mortality data for life table calculations for ages 85 to 99. Manton et al. showed that, even after adjusting for errors in age reporting in Medicare data, mortality rates plateau (or even decline) above age 95. Thus, there is debate about how to estimate life expectancy at ages 95+.

Other life expectancy calculations involve determining the life expectancy of people observed to die from specific causes of death (e.g., cancer, heart disease, or diabetes) or groups of causes of death (i.e., multiple-cause-of-death data). These calculations require assumptions about how various causes of death biologically compete with one another at specific ages – usually using the artificial assumption that causes of death are generated by independently operating disease processes.

To avoid assuming independence of competing risks, analyses must be made of the nature of the dependence of cause-specific mortality rates over time/age. One approach requires assessing the nature of the individual cause-specific hazard functions to determine the structure of correlations between those hazard functions. An alternate approach is to analyze the risk of death in longitudinally followed study populations in which measures are made of multiple health factors (e.g., disability measures in the National Long Term Care Survey, chronic disease risk factors in the Framingham Heart study) at multiple points in time before death. Measurements made before death can be used to describe health factor dynamics in the population, with the correlation of individual risk factor trends providing empirical evidence on the correlation of cause-specific mortality functions.

A second important form of life expectancy calculations is determination of active life expectancy, i.e., calculating the period of time that one can expect to live free of functional impairment. To calculate active life expectancy, ancillary data are needed on the age-specific prevalence of disability (e.g., determined by whether a person has a chronic impairment of an activity, or instrumental activity, of daily living) from population health survey data. These measures may be more informative about the health status of an economically highly developed country with a high life expectancy than classical life expectancy at birth measures, which do not describe the quality of life before death. The World Health Organization (WHO) has recently emphasized the importance of such measures in describing health improvements in developed countries over standard life expectancy calculations that describe only mortality differences.

Active life expectancy calculations also are frequently used in economic and policy analyses of human capital changes at late ages in aging populations. For example, in historical studies of Civil War veterans' health compared, for example, to the health of World War II veterans, the age at onset of various chronic diseases and disabilities was found to have significantly increased. Analyses of human capital, as might be used to study Social Security and Medicare benefits, require determining a life table function not only for persons surviving to a given age, but also for the subgroup who survive in a relatively intact functional state to that age. This type of calculation can help determine the potential labor force population at later ages, i.e., the proportion of the elderly population capable of performing socially and economically productive roles. Congressional debate in the United States now centers on further increasing the normal Social Security retirement age (e.g., to age 69 or older) from the currently programmed level (i.e., to age 67 in 2027; for persons born in 1960 and later).

Important in these analyses is the rate of improvement in life expectancy relative to active life expectancy (i.e., morbidity compression). This ratio reflects the efficiency of public health measures and medical therapeutic innovations in increasing human capital, as opposed to simply increasing length of life. For example, an analysis of this ratio starting in 1935 at Social Security inception, at 1965 at Medicare inception, and at various dates at which major biomedical breakthroughs have occurred showed a tendency for the proportion of life expectancy remaining at age 65 and 85 that is spent in functionally intact states to increase faster than total life expectancy after 1982 (**Table 1**). **Table 1** also projects these quantities to 2080. This suggests that recent health-care investments in Medicare and biomedical research have caused health to improve faster than survival.

These calculations also demonstrate a critical flaw in actuarial evaluations of the Social Security and

Table 1 Life expectancy (LE) and active life expectancy (ALE) at ages 65 and 85, US population

Year	*Age 65*				*Age 85*			
	Difference			*Ratio ALE to LE (%)*	*Difference*			*Ratio ALE to LE (%)*
	LE	*ALE*	*(disabled years)*		*LE*	*ALE*	*(disabled years)*	
1935	11.9	8.8	3.1	73.9	3.0	0.7	2.3	23.3
1965	15.0	10.9	4.1	72.7	5.4	1.5	3.9	27.8
1982	16.9	12.3	4.6	72.8	6.2	2.1	4.1	33.9
1999	17.7	13.9	3.8	78.5	6.4	3.0	3.4	46.9
2015	18.9	15.6	3.3	82.5	7.0	4.1	2.9	58.6
2022	19.4	16.4	3.0	84.5	7.3	4.6	2.7	63.0
2080	23.6	20.8	2.8	88.1	9.6	7.2	2.4	75.0

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Medicare programs. Specifically, changes in life expectancy projected for Social Security are not calculated by taking into account changes in the level – and nature – of Medicare investment in improving health outcomes. Social Security Administration (SSA) life expectancy projections should reflect the effects of Medicare expenditures in changing US health and functioning – especially in an era of rapid innovations in biomedical technology. The longer term the projections, the greater the potential accumulated effects of this model misspecification.

One use of life expectancy measures is to compare the relative efficacy of health-care expenditures across countries. Such comparisons are often done to show the advantage of the Japanese and European health-care systems over that of the United States. In 2004, Japan's life expectancy was the highest among major economic powers, with an estimated male life expectancy of 77.9 years and female life expectancy of 84.6 years. Sweden, Switzerland, and France were close. Official US life expectancy estimates are currently several years behind those countries. More detailed analyses suggested that much of those differences are due to the greater size and heterogeneity of the US population.

The highest recorded human life expectancy observed to date is for the small European country of Andorra, with a male life expectancy of 80.6 years and a female life expectancy of 86.6 years. In the case of Andorra and Japan, the theoretical limits to life expectancy postulated by Olshanky et al. and Fries of 80 to 85 years have been materially exceeded.

These observations highlight the difficulty of inferring longevity, a theoretical potential of the human organism, from trends in the empirical measures of life expectancy, which reflect the interactions of a heterogeneous human physiology with a highly variable and dynamic environment. Fogel and Costa argued that longevity is a function of multiple environmental factors generated through a process they call techno-physiological evolution. In this model, human life expectancy will evolve far more rapidly than could be expected under a genetic model. Such a model may explain, for example, why the recent obesity epidemic failed to have the serious health implications its proponents argued.

The United States often fares poorly in life expectancy comparisons because it is larger ($\sim$293 million) and more ethnically, socially, and economically heterogeneous than the Japanese ($\sim$127 million) and Swedish populations. Adjusting for the heterogeneity of the US population and related measurement problems (e.g., for the extremely high mortality of undocumented Mexican farm workers) shows the United States to have a much higher life expectancy at birth (80.6 years) for the large majority of persons who are more fully integrated into the US health-care system (e.g., persons covered by private and public health insurance, Medicare and Medicaid). This is much closer to the life expectancy currently observed in Japan (i.e., less than a year's difference at birth).

Life Expectancy Calculated Conditionally on Physiological Covariates and Their Dynamics

A major concern in estimating life expectancy is to perform calculations for persons in specific health states in which health states may change over time. Health states can be discrete, described by a set of continuous covariates, or a mix of discrete and continuous changes. One approach uses a multivariate stochastic process model to describe changes in the distribution of a longitudinally followed population on j health variables. This model, to include covariates, requires that two sets of equations be estimated. One, of j autoregressive equations, represents the change over time of the j risk factors for individuals in the population. Those dynamic equations describe the rate of change in risk factors as a function of the individual's prior health status and a stochastic or error term. Mortality is described by a quadratic hazard function in which each coefficient in the hazard function is an explicit function of chronological age. This type of model may more accurately transfer effect estimates across populations since (1) it has the health effects appropriately modeled over time/age and (2) it better describes risk factor interactions. Estimation of the parameters for the two sets of equations requires longitudinal data in which persons are followed over a significant period of time prior to death and are assessed on multiple variables at multiple points in time during follow-up (e.g., 50-year follow-up of the Framingham Heart Study; Honolulu Heart Study).

The additional parameters in the two sets of equations enhances the ability to describe the biological mechanisms driving changes in mortality, health, functioning, and life expectancy, making them more useful for health forecasting and health policy evaluation purposes. Such models are also of benefit in comparing the health consequences of particular medical innovations (e.g., use of progenitor cell transplants to reverse atherosclerotic changes in adults compared to interventions in more traditional risk factor interventions). Olshansky et al. critiqued the use of mortality forecasting models that did not contain measures of health status or describe disease mechanisms as extrapolation. Mechanism-based

models are more likely to detect cause-specific mortality trend turning points, such as observed for cancer in 1990.

One limitation in the use of health-state models is that many of the longitudinal study populations that could be used to parameterize the models are in small geographic areas (e.g., in Framingham, Massachusetts) so that they do not represent the experience of the US population (e.g., in Framingham there are few Hispanics or African Americans). Furthermore, such studies often have limited follow-up periods (the initial Framingham population study is exceptional in having followed the sample for over 50 years). As a consequence of limitations in longitudinal study data, it is often necessary to combine data from multiple studies. Use of more detailed health-state models is a benefit in combining data. With a more detailed parametric structure, differences between populations can be more completely and precisely adjusted when combining model parameters estimated from individual data sets. For example, using data from four of the WHO Monica studies of cardiovascular disease and risk factors, comparative studies could be done by modifying parameters to control for differences in the distribution of risk factors in China, Germany, the United States, and Russia.

There are a few US longitudinal survey series, such as the 1982 to 2004 National Long Term Care Survey (NLTCS) and the 1960 to 2000 National Health and Nutrition Examination Survey (NHANES) series, which are nationally representative and in which a range of risk factors and social and economic variables are measured. By applying health-state models to such longitudinal data sets, it is feasible to produce national estimates of survival and life expectancy adjusted for risk covariate distributions and their change.

Future uses of life expectancy measures will likely require their calculation to better reflect the dynamics of multiple covariables measured in multiple data sets. Unfortunately, this has often been attempted using non-linear regression models that did not satisfy the dynamics of conditions represented in the data. For example, though Cox proportional hazard models were used to assess the benefits of hormone replacement therapy in the Heart and Estrogen/Progestin Replacement Study (HERS) I and II study, these data did not fulfill the model assumption that the time-dependent hazards in different groups were proportional over time, calling into question the conclusions of those analyses. Specifically, there were concerns that accumulating benefits of the hormone replacement therapy on circulatory disease were hidden by an early increase in circulatory disease risk, possibly due to early pro-inflammatory states.

This raises other concerns about the mathematical form of models used to relate covariate dynamics to survival outcomes and life expectancy. Specifically, logistic models do not naturally describe the long-term behavior of stochastic processes. Thus, logistic functions are generally not satisfactory for calculating life table functions and life expectancy in the presence of the effects of multiple dynamic (non-fixed) covariates for studies with measures made at different time intervals. A model mathematically appropriate for such calculations is described in Woodbury et al., in which the model with separate risk factor dynamic and mortality equations was used to calculate life table parameters (including life expectancy) conditional upon the trajectories of the means and variances of multiple covariates using a system of five differential equations.

Life Expectancy: Current and Future Values Based on Death Dynamics

Problems can occur in calculating life expectancy when assembling mortality data in various meta-analytic studies, especially when studies involve very different age ranges. This is sometimes due to inconsistent use of proportional and attributable risk calculations. Such errors were made when epidemiologists at the Centers for Disease Control (CDC) tried to demonstrate that obesity had nearly overtaken smoking as the number one risk factor for mortality in the United States. In Flegal et al., the methodological errors in the earlier CDC calculations leading to the declaration of an obesity epidemic were identified. It was determined that there was an error of between 17 and 100% due to such methodological errors. Furthermore, the calibration of the survival functions used in the model was based, in part, on old data on the relation of mortality to body mass index (BMI). In more recent data, the relation of BMI to mortality was found to have significantly attenuated – probably due to improvement in the medical management of major risk factors (e.g., hypertension, hypercholesterolemia, elevated blood sugar), especially in high-risk groups such as those with elevated BMI and adult diabetics.

In analyses of survival data from several recent NHANES, it was found that (1) the BMI range (25–30) called overweight was associated with a large reduction (86 000) in the number of expected deaths relative to the so-called normal weight category of 18.6–24.9; (2) underweight, especially at later ages, was an unhealthy state associated with significant mortality; and (3) the net effect of changes in BMI in the United States was, as a consequence,

small – ~25 000 deaths (i.e., the seventh ranked cause of death). Over 40 years (1960 to 2000), cardiovascular disease risk factors (smoking, hypertension, cholesterol) declined in all BMI categories, with risk factor declines in the population of obese persons being more rapid than in normal-weight persons – a finding consistent with the faster reduction in risk factors observed among diabetics.

Arguments about life expectancy changes and obesity trends (i.e., those finding adverse health effects of an obesity epidemic versus those finding lower excess mortality risks) do not reflect the theoretical, historical, and empirical arguments of Fogel and Costa about the effects of economic and social development on life expectancy and BMI trends – and possible changes in trends in the future. Their arguments suggest that the normal body weight (implying the healthiest BMI) has changed over time (e.g., since the Civil War in the United States) due to public health and other improvements in health care that changed health risks at various BMIs. Specifically, Fogel and Costa, analyzing a wide range of historical data sets (especially a study of Union Army Civil War veterans assessed for pensions and the separate, more medically detailed, Gould study of 23 785 persons assessed at entry to the army during the Civil War), found that the BMI optimally associated with survival and health grew after the Civil War to levels that the CDC currently categorizes as overweight; i.e., the current Waaler surface for US males had a minimum mortality rate at a BMI of 26.4, which can be compared to the 25–30 range categorized by CDC as overweight. Fogel's calculations are supported by new data and analyses of increases in BMI by Flegal et al. and others showing that the overweight category (BMI of 25 to 29.9) was associated with a large decrease in expected deaths (86 000 fewer than expected) using recent NHANES data and related BMI-specific mortality follow-up. The reductions appear due to the better medical management of risk factors in various overweight and diabetic groups. Costa found that the historical (100 year plus) increase in average BMI in males was correlated with a decrease in abdominal body fat, improved vital capacity, and an increase in lean body mass.

These and other long-term observations led Fogel and Costa to posit the theory of techno-physiological evolution, i.e., that environmental and technical changes (e.g., improved nutrition and sanitation) lead to epigenetic modification of physiological parameters controlling metabolism, energy production, and organ dysfunction manifest as chronic disease at late ages. If such a theory were valid, the use of model life table functions at advanced ages to deal with imprecise data over time would be invalid (i.e., potentially tautological) if the shape of hazard function could theoretically change as a function of the environmental changes.

Deaton, evaluating the implications of the techno-physiological evolution and its effects on life expectancy dynamics, suggested that one factor underrepresented in the Fogel model is the recent benefit of biomedical innovations on the range of therapeutic options now available. Deaton cited the work of health economists such as Cutler and McClellan, which indicate that – for specific medical problems – there have been rapid increases in the number of productive life years due to improved medical therapies and that these contributed to the growth of human capital (i.e., more rapid active than total life expectancy increases) at later ages. Manton et al. estimated what increases in investment in basic biomedical research are optimal relative to increasing productivity and expanding human capital (active life expectancy) in a population experiencing rapid aging. These models, based on the work of Romer and Jones and Williams, suggest that even the recent doubling of the National Institutes of Health (NIH) budget leaves research investment far below the optimal level of investment in medicine and related biomedical research areas (e.g., nanotechnology; development of new biological materials) to best stimulate (US) economic growth and increase active – as well as total – life expectancy.

Life Expectancy and Longevity

One critical use of life expectancy analyses in studies of aging is to determine how aging relates to the longevity – and senescent processes – of a given species. Life expectancy is a statistical quality determined from data. Longevity has a relation to life expectancy similar to that of fecundity to fertility. That is, life expectancy and fertility are observed. Both fecundity and longevity are theoretical latent biological traits of individuals in a population. Life expectancy calculations may be used to infer the trajectory of the unobservable trait longevity only by using additional data on physiological changes before death or biological theory. The analysis becomes complex when longevity changes – in addition to life expectancy – in response to environmental factors as in the techno-physiological evolution model of Fogel and Costa. This emphasizes the conceptual problems, as well as methodological and measurement difficulties, in relating longevity and life expectancy, which are partially resolvable by measuring health changes prior to death. A complete resolution, however, is necessary to successfully project long-term life expectancy trends for determining future

population growth, rate of population aging, and the structure, fiscal stability, and performance of programs like Medicare and Social Security.

See also: Medicare and Medicaid and Economic Policy of Health Care; Social Security.

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Life Review

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Glossary

Autobiographical Memory – Memories of specific events occurring in an individual's daily experience that are stored without the benefit of conscious memory goal activities on the part of the individual.

Guided Autobiography – Topical approach to the collection of autobiographical data. Life review in a systematic manner.

Narrative (or Experiential) Gerontology – The field of study by which the inner perspective of aging can be revealed.

Oral History – Individual account that becomes a source of history.

Reminiscence – The process of recollecting past experiences and events, or the experiences or events recollected. One-on-one and group reminiscence can be therapeutic but not evaluative, thereby distinguishing reminiscence from life review.

Introduction

The life review is a normal developmental task of the later years characterized by the return of memories and past conflicts, which can result in resolution, reconciliation, atonement, integration, and serenity. It can occur spontaneously or can be structured.

Structured evaluative life review is practiced for research and therapeutic purposes.

One key goal of early work on life review was to demonstrate that the process of life review in older people is not a pathological condition, but rather is a normal developmental task of the later years that may in certain cases contribute to psychological dysfunction and in other cases to psychological growth, including resolution of past conflicts, reconciliation with significant others, atonement for past wrongdoing, personality integration, and serenity.

The concept of life review was used originally to refer to the older person's process of review and evaluation of their lives within the context of intensive psychotherapy and research interviews. The life review concept is distinguished from reminiscence. A related concept is guided autobiography.

Origin of the Theoretical Concept

In 1961, R. N. Butler postulated the universal occurrence in older persons of an inner experience or mental process he called the life review. He proposed that life review helps account for the increased reminiscence in the elderly, contributes to the occurrence of certain late-life disorders, particularly depression, and participates in the evolution of such characteristics as candor, serenity, and wisdom among certain older persons.

Allusions to a life-reviewing process have been common in the literature of various historical periods, from Aristotle to Somerset Maugham. G. Stanley Hall adumbrated a somewhat similar idea in his 1922 work, *Senescence: The Last Half of Life,* and intimations of the life review can also be found in Gordon W. Allport's 1937 book, *Personality: A Psychological Interpretation,* in which he emphasized the continuity of personal memories.

In contrast to the prevailing tendency, which at that time was to identify reminiscence in the elderly with psychological dysfunction, and, thus, to regard it essentially as a symptom, Butler saw the life review as a naturally occurring, universal mental process characterized by the progressive return to consciousness of past experiences, particularly the resurgence of unresolved conflicts. Simultaneously and normally, these revived experiences and conflicts can be surveyed and reintegrated. Presumably this process is prompted by the realization of approaching dissolution and death and the inability to maintain one's sense of personal invulnerability. It is further shaped by contemporaneous psychosocial experiences, and its nature and outcome are affected by the lifelong unfolding of character.

The life review potentially proceeds toward personality reorganization. Generally, the more intense the unresolved life conflicts, the more work remains to be accomplished toward reintegration.

The life review is not synonymous with but includes reminiscence; it is one level or type of reminiscence. It can occur silently without obvious manifestations. In mild form, the life review is reflected by increased reminiscence, mild nostalgia, and mild regret. In severe form, it includes anxiety, guilt, despair, and depression. One case study presented by Butler describes a woman who in the course of reviewing her life became remarkably abusive, violent toward others, and physically damaging to herself. It became clear that past actions justified her sense of guilt. In such a case, a simple reassuring response is valueless. Discussing the events or situations that provoked the guilt reactions and confronting the feelings that are prompted by the life review are more productive responses (*see* Reminiscence).

In the extreme, life review may involve the excessive preoccupation of the older person with his or her past, and it may proceed to a state approximating terror and result in suicide. Thus, although the life review process may be universal and normative and contribute to a reconstruction of personality, its outcome can in extreme cases include psychopathology. The more severe affective and behavioral consequences tend to occur when the process occurs in isolation in those who have been deeply affected by increasing contraction of life attachments and notable psychosocial discontinuities such as forced retirement and death of a spouse. The most tragic situation may be that of the person whose increasing but only partial insight into the past leads to a sense of total waste. Just as one is about to die, one may experience the horrifying feeling that one has never lived or may see oneself realistically and in some sense as inadequate.

Samuel Beckett's one-act play, *Krapp's Last Tape,* is a most compelling modern existential illustration of the life review. An old man listens uncomprehendingly to recordings he made as a young man in happier times. He is listening to a total stranger. The play asks, can he be regarded as the same human being in youth and in old age? Novelists and poets have, of course, used reminiscence or life review in their works, for example, the writings of Marcel Proust, James Joyce, Joyce Cary, and many others. Writers, poets, and teachers have deliberately used life review in their teaching, writing, and filmmaking (*see* Literary Representation of Aging). Referring to the 1980s to the early 2000s, and given the growing number of autobiographies and memoirs,

Patricia Hampl has called the memoir "the signature genre of our age."

People of all ages review their pasts at various times in life, especially when confronted with a crisis. Life review is common, for example, in middle age when one begins to see death at a closer distance. The philosopher Schopenhauer even remarked that middle age is that point in time when one begins to count backward from death rather than forward from birth. However, one may ask, do all life reviews serve the same functions, regardless of when they happen? Does life review in old age have particular characteristics, especially when it occurs in the face of death? As originally formulated, life review is defined as the latter.

The Nature of Memory

Memory is a complex amalgam of the senses, perception, integration, and cognition. Memory, reminiscence, life review, autobiographical memory, life story, narrative, oral history, and related concepts may one day be understood from the neurophysiological and molecular-cellular perspectives. The neurotransmitter acetylcholine is especially crucial to memory, but memory, so important to adaptation, does not depend upon one neurotransmitter alone. Memory is apparently located in the hippocampus and the amygdala. The latter is associated with memories of fear. Gender may play a role in memory function, because estrogen and other hormones affect the brain. Corticosteroids have been associated with stress and 'brain aging.' In the 1940s, neurosurgeon William Penfeld and others at McGill University in Canada demonstrated the human brain's information storage and retrieval capacity. With electrodes, they stimulated exposed temporal brain lobes of neurological patients under a local anesthetic. The process evoked vivid memories of isolated and even insignificant past events (*see* Brain and Central Nervous System; Endocrine Function and Dysfunction). Eric Kandel's work has revealed the molecular basis of memory using a snail, Aplysia, as the animal model.

Researchers still have much to learn about how the brain integrates and organizes information into categories. In *Remembering,* British psychologist Sir Frederick C. Bartlett argued that all new learning builds upon existing knowledge. A single stimulus can bring forth myriad memories, a fact novelist Marcel Proust poignantly illustrated in the 'Combray' section of his book *Remembrance of Things Past,* when the protagonist experiences a flood of memories of his youth triggered by eating a cake he enjoyed as a child. However, there may not be a single bank or library of stored information that can be called up at any time. Special stimuli might be required to reveal what may be deeply repressed. On the other hand, some information might be easily recalled or retrieved when specific stimuli are provided. One researcher distinguished six types of reminiscence: integrative, instrumental, informative, narrative, escapist, and obsessive. Instrumental reminiscing, for example, was reviewing past experiences to solve present problems. Age and life stage may also be factors in memory (e.g., childhood amnesia) (*see* Memory). Memory can be uncertain and faulty, and may vary at different stages of life and under varied circumstances in healthy individuals. When brain disease occurs, as in Alzheimer's disease, many functions, including memory, are directly impaired.

Life Review as Psychotherapy

The life review and similar autobiographical concepts have been suggested as psychotherapeutic techniques. The Martin Method, in which the client is asked to relate his or her life history in detail; life review therapy; guided autobiography; and reminiscence and structured life review therapy are among the therapeutic techniques related to or using life review.

One can use family albums, scrapbooks, cherished possessions, and other visual images to evoke crucial memories. Genealogy, reunions, pilgrimages to one's ancestral home, and family archives have also been used therapeutically. Memories can involve all of the senses – taste, smell, vision, hearing, and touch – and each may be exploited to evoke memories of the past. For Charles Dickens, for example, one whiff of a paste would bring back the anguish of his early years. Music is also a powerful stimulus for the flow of memories. The Hebrew Home for the Aged in New York City created in 1995 a lovely garden intended to trigger positive memories from the past. A porch swing evokes a bygone era, as does a water fountain made from a fire hydrant. The guided biography method proposed by Birren consists of creating a composition responding to topics such as 'my family of origin.'

Life review therapy or guided autobiography has been used with those who may not spontaneously report reminiscences. In structured life review, specific questions about one's life and conflicts are explored. Life review therapy may be conducted in group settings. For example, the family as a whole can participate in life review therapy. Such family life review has therapeutic advantages because it may lead to consensus and clarification of specific family issues.

Life review therapy has been used with institutionalized and demented older persons. Remote memory is not as affected in the early stages of dementia as much as recent memory is. Life review and reminiscence techniques are widely used by nurses in nursing homes and as part of hospice care. The life review has been used in caring for terminally ill young adults with AIDS as well as older people. The National Hospice Foundation has used the concept of the life review and created a comprehensive guide for persons of all ages. Such a review should be available for those dying patients who wish to receive therapy that offers personal, existential, and spiritual help as well as palliative nursing and medicine (*see* Hospice).

Professionals in nursing, social work, occupational therapy, physical therapy, arts and music therapy, psychology, medicine, and psychiatry have advocated reminiscence and life review as ways to help patients achieve self-esteem. The life review may aid people to resolve conflicts in their lives. Part of the therapeutic value of life review therapy in older persons may be the simple fact that someone is listening to them and that approaching death, affording them little time, is a potent incentive for positive change, such as improvement in mood, increased self-esteem, and so on (*see* Self Esteem). Forgiveness of others is an important element in reconciliation.

There is a moral dimension to the life review because one looks evaluatively at one's self, one's behavior, one's guilt. One stands in judgment of the life one has led. Atonement, expiation, redemption, reconciliation, and meaning in life are powerful potential positive outcomes of the life review. It is necessary to explore guilt, confess, and not deny it, as well as experience atonement and reconciliation, especially at the end of life. With suffering may come resolution, new insight, and self-discovery.

Fears about time running out may be reduced and replaced with a sense of immediacy, or the here and now. The elemental things in life – children, friendship, nature, human touching (physical and emotional), colors, shapes – gain significance as people sort out the more important things in life from the less important.

The Validity of the Life Review

Although the concept of life review has become entrenched in both the literature and the practice of gerontology, nursing, social work, and to some degree psychology and psychiatry, aspects of the life review have been called into question, and many questions remain unanswered. For example, how does one determine whether memories have a factual basis or are defensive distortions? How effective or even possible is external verification of memories? Studies show, for example, that mothers' memories of the timing of the most simple events in their children's development, such as toilet training, are not always accurate. What are the interconnections between emotions and memories? Personal myths emerge from childhood and may be held throughout life, affecting one's self-image and most certainly influencing reminiscences. How do self-representations change over time? What are the connections between memories and identity or self-definition? What is more important, that which is remembered or that which is forgotten, or both? How does one confirm findings that people regret most the things that they failed to do rather than the things they did do?

The life review helps both uncover and stabilize one's past selfhood. Tolstoy at age 81 said, "I remember very vividly that I am conscious of myself in exactly the same way now, at 81, as I was conscious of myself, my 'I' at five or six years of age." Consciousness is immovable. Due to this alone there is a movement that we call time. If time moves on, then there must be something that stands still; the consciousness of my 'I' stands still. This is a common feeling, substantiated by extensive work at the National Institute on Aging's Baltimore Longitudinal Study of Aging.

Some careful studies have demonstrated the effect of life review on dependent variables, such as depression and life satisfaction. It is true that much work still needs to be done to effectively operationalize outcome measures. But how does one 'measure' meaning in life, guilt and expiation, redemption, and reconciliation?

It has been said that the life review may be specific to Western society because of its focus on individualism. However, there is an active program on reminiscence in Japan, for example, and meditation on death and the end of life is common in other Asian countries.

Is the life review a universal occurrence? Studies report that between 49 and 84.1% of older persons have reviewed their lives or are currently reviewing them. Of course, this does not preclude the possibility that all persons might eventually do so. One study showed that those closer to death showed significantly less reminiscence activity and significantly less introspection when compared with matched controls, but this could be consistent with the original theoretical formulation that suggested post-review serenity or ataraxia. Subjects in these studies were not always followed through to the time of death. Some individuals may review their lives only

on their deathbed. A further complication is the difficulty of determining whether the life review has already occurred, because the process is not always a conscious one. The life review often occurs over a considerable period of time and only after a significant relationship has been established with either a mental health professional or a trained empathic listener.

One study reported asking questions such as the following: 'Some people review and evaluate their past in order to get an overall picture of their life. This is called the life review. Have you reviewed or are you currently reviewing your life?' This question does not always give access to the life review, and it might not be immediately answerable by all individuals. Such a literal, objective, or conscious approach also contrasts with the context of intensive psychotherapy and intensive research interviews that led to the original formulation. This formulation assumed the existence of the unconscious, the division of the mind in psychoanalytic theory that contains memories or repressed desires, not subject to conscious perception or control but often affecting conscious thought and behavior.

The Value and Use of Oral History and Autobiography

The need to engage in life review has prompted the writing of many major memoirs, autobiographies, and treatises summarizing the authors' life work, especially since the seventeenth century. People maintain diaries and write memoirs and autobiographies because they value their lives and feel that they have important ideas or information to convey to others or want to 'set the record straight' or gain revenge against their enemies.

There are life review and family history training manuals and guides to help people collect on audio- or videotape their life stories to leave to their families and others. Businesses have been created to sell audio- and videotapes and books made from interviews. Several aging organizations have developed materials to help people create their autobiographies or life reviews. In Britain, Age Exchange, The Reminiscence Centre, has developed *A Practical Guide to Reminiscence*. Age Exchange focuses on 'making memories matter.' Its goal is to "improve the quality of life for older people by emphasizing the value of their reminiscences to old and young through pioneering artistic, educational, and welfare activities." Age Exchange has the only professional Reminiscence Theatre company in the United Kingdom, to which Londoners have given their memories of living through the blitz in World War II. StoryCorps is a project created to tape the stories of everyday people and store them at the Library of Congress.

Autobiography is one literary genre that potentially gives everyone the opportunity to become 'someone.' This democratic process gives one the chance to speak about oneself, which can, of course, lead to reinvention of the self, self-indulgence, shameless vanity and egotism, and defense and revenge, or offer a sensitive, valid portrait of oneself. In some measure whatever one writes, however biased or fabricated, provides, to a degree, information about the individual or his or her personality. External historical observations and the memories and commentaries of others may be available to evaluate the validity of the contents of autobiographies. Some public life reviews can be painful and controversial, such as Robert S. McNamara's *In Retrospect: The Tragedy and Lessons of Vietnam,* published in 1995. His life review was also provided in the film documentary 'Fog of War' in 2004.

Behaviorism brushed aside various subjective sources of information about personality. However, oral histories and autobiographies constitute a rich source for information in such fields as anthropology, history, and literature. For example, the popular *Foxfire* books of Eliot Wigginton, which recorded the lives of people living in Georgia, preserve cultural history as well as the lives and skills of everyday people. Another example, the 1993 oral history *Having Our Say: The Delany Sisters' First 100 Years* by Sarah L. Delany and A. Elizabeth Delany with Amy Hill Hearth, was a best-seller and was made into a Broadway play. It provides a first-hand account of what it has been like to live as an African American in the United States in the twentieth century.

Life Review and New Directions in Psychiatry

What will happen now that psychiatrists have moved further away from psychodynamics and the inner life to the use of psychoactive medications in their practices? Perhaps more people will feel good and healthier faster. Painful feelings will be assuaged. But if medications were utilized in the context of ongoing psychotherapy, self-understanding might also grow. There need not be a dichotomy here, for both psychoactive medications, such as antidepressants, and psychotherapy should be concurrent and reinforcing.

What about the fact that relatively few gerontologists and psychologists have spent significant

amounts of time being with and listening to older people? They will lose opportunities to better understand the inner life if they depend upon drugs alone and if psychologists and gerontologists do not explore human personalities in depth. Researchers do not know how lasting either psychopharmacological or psychotherapeutic approaches are, but it is hard to believe that a pill gets to the bottom of genuine guilt due to acts of commission or omission. Is there no place for some measure of human suffering? Is there not also a time for celebration when painful issues are successfully resolved?

The life review concept has contributed to a better understanding of late-life and end-of-life development as well as development across the life span. It has helped demonstrate the therapeutic value of reminiscence for older people and helped eliminate prejudice against those who reminisce. But people and their life stories are more complex than any presently available methods for their study allow. Therefore, researchers must encourage further study of life span developmental psychology.

Summary

Memory is a great force for human adaptation in general and is important to social evolution. The survival value of memory both to the individual and to society cannot be denied. Life review is important in itself; in a sense, it is analogous to undifferentiated, basic research. It adds to self-knowledge per se, independent of consequences. And, by extension, one learns of the lives of others and how lives might be led. As virtue is its own reward, so, too, is the life review, for as Socrates said, "The unexamined life is not worth living." Put more positively, there are chances for pain, anger, guilt, and grief, but there are also opportunities for resolution and celebration, for affirmation and hope, for reconciliation and personal growth.

Although a majority of persons may undergo a life review, it may not be accessible and reportable in a significant minority. Memories may be deeply repressed. Moreover, life reviewers may be more introspective than those who do not appear to review. Studies of subgroups might help us to better understand such differences in personality.

It has been suggested that the life review might not be universal or even exclusively precipitated by approaching death. Yet it is remarkably common among older people, and the prospect of death is one of its most common triggers. Only in old age with the proximity of death can one truly experience a personal sense of the entire life cycle. That makes old age a unique stage of life and makes the review of life at that time equally unique.

See also: Brain and Central Nervous System; Endocrine Function and Dysfunction; Hospice; Literary Representation of Aging; Memory; Reminiscence; Self Esteem.

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Life Satisfaction

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Glossary

Affect – A broad class of emotional processes, including feelings and moods.

Cognition – A general concept comprising all forms of knowing, including perceiving, imagining, reasoning, and judging.

Happiness – The extent to which positive feelings outweigh negative feelings. The relatively temporary affective feelings of the present moment. Often, the time period of the 'past few weeks' is used to anchor the assessment.

Morale – A future-oriented optimism or pessimism regarding the problems and opportunities associated with living and aging. Morale refers to how well people feel they fit into their social and physical environments and their acceptance of those things they can not change.

Psychological Well-Being – A general concept representing positive psychological functioning. The extent to which people are happy, experience positive affect, and do not experience depression and anxiety.

Quality of Life – A broad concept referring to overall population and/or individual-level well-being, assessed with a wide variety of objective and subjective indicators. There is some controversy about whether the quality of life concept can be defined precisely enough to serve as a legitimate social scientific construct.

Satisfaction – Implies an act of judgment, a comparison of what people have to what they expect in terms of their whole life or some specific part of it. The more their achievements fall short of their aspirations, the greater the level of dissatisfaction. Satisfaction has a past orientation, an evaluation of how things have gone up to the present.

Introduction

The quality of life for a society or group is often determined by using objective indicators such as gross national income, frequency of high-risk health behaviors, quality of the environment, and levels of crime, suicide, public violence, and family disintegration. An individual's quality of life can also be characterized on the basis of these types of objective factors. Alternatively, measures of subjective well-being have been developed based on the belief that the psychological quality of a person's life can not be understood simply from knowledge of these objective circumstances. Life satisfaction is a popular subjective well-being measure of quality of life. People are typically asked to rate their satisfaction with life as a whole or some aspect of it.

Focus of Life Satisfaction Research

Life satisfaction is one of the oldest research issues in the social scientific study of aging. Initially, this research focused on pathology and coping, but later the issue became perceptions of quality of life. Life satisfaction and other subjective well-being measures have been of considerable importance in gerontology. Researchers and policy makers are attempting to better understand the impact on quality of life of disability, changes in health status, caregiving, bereavement, retirement, role transitions and loss, diminishing social networks, modifications in activity involvement, and personality development over the life course.

Two issues have dominated research on subjective well-being in the field of gerontology. The first concerns how best to conceptualize and measure subjective well-being. Life satisfaction is only one of several competing subjective well-being constructs, and researchers continue to work at developing appropriate measures. The second issue involves the identification of those factors in people's lives that influence their subjective well-being. A substantial amount of research focusing on this issue and using the life satisfaction construct has been reported. The impact on life satisfaction of various interventions, programs, and policies directed at older adults has also been of recent interest.

Constructs and Measures

In addition to life satisfaction, other popular constructs used to conceptualize subjective well-being in the study of older adults include happiness, psychological well-being, and morale. Paper-and-pencil scales have been developed to measure these constructs. Standardized scales used for measuring life satisfaction include Cantril's Self-Anchoring Scale, the Neugarten Life Satisfaction Index and modifications

of it by Wood and colleagues, the Andrews and Withey Delighted-Terrible Faces Scale, and the Satisfaction with Life Scale developed by Diener and colleagues. A variety of single-item measures of life satisfaction have also been used in many studies. The most frequently used happiness and psychological well-being scale is the Bradburn Affect-Balance Scale, and morale is typically measured with The Philadelphia Geriatric Center Morale Scale.

A major problem with the subjective well-being research in gerontology has been the lack of consistency in defining, measuring, and using the terms psychological well-being, happiness, life satisfaction, and morale. In fact, these concepts and their measures often have been used interchangeably. However, they appear to differ on a variety of dimensions. First, there is time orientation. Satisfaction is seen to have a past, happiness a present, and morale a future orientation. Second, these constructs and measures vary in how enduring or temporary the state of subjective well-being is thought to be. Life satisfaction and morale scales measure more enduring and stable cognitions, while happiness scales measure more temporary and transient affective states. Third, the measures of these constructs differ to the extent that their items allow the assessment of both positive and negative life experiences as distinct aspects of subjective well-being. Some research evidence suggests that the positive and negative aspects of well-being are not opposite ends of a continuum, but rather separate dimensions that reflect satisfaction with different components of life (e.g., external social conditions such as friends and activities versus inner psychological conditions such as self-esteem and health, respectively). Finally, the various measures used differ in terms of whether they assess global well-being or well-being in specific domains of life (e.g., work, family, leisure, and neighborhood). By examining satisfaction with each of these domains, some researchers believe that a more accurate picture of well-being can be obtained. Researchers examining different domains of life have primarily used satisfaction measures, and specialized areas of research have been developed on single domains, such as job and leisure satisfaction.

Substantial correlations have been found to exist among the satisfaction, morale, and happiness scales, suggesting that they measure different facets of the same underlying construct. These findings are not too surprising given that the most popular measures share a number of scale items in common. However, these constructs and scales are not completely interchangeable. Research has shown that various well-being constructs are related differently to a wide variety of predictors of subjective well-being.

Although researchers continue to examine empirically the internal structure of these measures and fine-tune them for use in specific studies of older adults, other measures have been developed. For example, the Memorial University of Newfoundland Scale of Happiness and a shorter version, the Short Happiness and Affect Research Protocol, are used to measure both the enduring cognitive and the more immediate transitory affective dimensions of subjective well-being among older adults. In addition, these scales allow the systematic assessment of both the positive and negative content of life experience.

Another approach to conceptualizing and measuring subjective well-being in later life also has been suggested. Several authors have proposed breaking with past work and reconceptualizing subjective well-being, successful aging, and aging well by defining it as personal development and adjustment. They argue that measures of well-being based on the notions of satisfaction, happiness, and morale are too tied to concepts that were developed independently, and that attempts to integrate them into some superordinate subjective well-being construct fails to provide a strong theoretical basis for the development of better measures and future research. A few studies have been reported that use measures that reflect a more developmental view of psychological health and well-being (e.g., generativity, self-acceptance, autonomy, environmental mastery, purpose in life, and personal growth) based on major personality and life span theories such as those of Erikson, Rogers, and Maslow. Feelings of having lived up to one's potential and identity development earlier in life have been found to predict life satisfaction later in the life course.

In spite of the difficulties of conceptualization and measurement, a great deal of research has been done on the factors that influence subjective well-being. In much of this research, subjective well-being has been conceptualized as life satisfaction. Also, survey methodology has been predominantly used to examine a wide variety of predictors of life satisfaction. Consequently, the psychological and social factors or mechanisms linking these predictors and life satisfaction have not been explored. The rationale for the linkage is often quite speculative. As will become apparent, many of the predictors are themselves linked in complex ways that make it difficult to sort out likely causes and effects. For example, research done on the influence of housing and living environment on life satisfaction suggests that older adults living in their own residences experience higher life satisfaction than older adults living in long-term care settings such as nursing homes. Little research has been reported that explores the reasons

this relationship exists, though we can speculate that being in familiar and meaningful environments in close proximity to friends and neighbors may have something to do with the relationship. However, this relationship also is likely linked to other factors that have been found to be important. Older adults who live in their own residences are likely younger, healthier, more physically independent, and wealthier – all factors that predict higher levels of life satisfaction. With these qualifications in mind, the major predictors and correlates of life satisfaction among older adults are identified and discussed.

Predictors and Correlates

Health Status and Functional Ability

Research with community and clinical populations has consistently demonstrated that individuals in poor physical health are less satisfied with their lives than those in good health, and subjective health perceptions are a better index of life satisfaction than number of actual health problems. Health has also been found to influence people's estimates of their future life satisfaction and changes in life satisfaction over time. Though the limited cross-cultural research reported suggests that the physical health and life satisfaction relationship is fairly universal, health status may affect life satisfaction for some groups more than others. For example, perceived health is the best single predictor of life satisfaction for elderly Whites but may not be for elderly African Americans. Health problems also appear to have a greater negative impact on females than males, and on older than younger elderly adults.

Certain health problems are more strongly related to life satisfaction than others. Functional limitations that complicate daily living and interaction with others (e.g., control of bladder/bowel, visual and hearing impairments, limitations in mobility) have been found to be more strongly negatively correlated with life satisfaction than chronic disorders with established treatments. Longstanding illnesses or chronic health problems may have an indirect effect on life satisfaction by reducing activity levels. Declining health may lead not only to difficulties in performing everyday chores, but also to difficulties in maintaining social contacts and continuing valued leisure activities. However, it remains unclear how variables such as type of illness and time of onset influence life satisfaction.

Researchers have begun to identify factors (e.g., support systems, treatment programs, coping strategies) that may play an important role in buffering the effects of decreased health status on life satisfaction. Although more attention has been given to the impact of caregiving on the caregiver than the person needing care, research has suggested that older adults who require assistance with the activities of daily living have lower levels of life satisfaction. Consistent with these findings, formal support but not informal assistance has been found to reduce the deleterious effects of perceived health problems on life satisfaction. Involvement in adult day programs has been found to lead to significant improvements in life satisfaction for older adults with disabilities or illnesses and their informal partners in care. Adult day programs may be most effective when they are used consistently starting early in the caregiving career and over longer periods of time. Positive cognitive coping (i.e., modifying the meaning of the problem) rather than direct action coping (i.e., behavioral approaches) has been shown to buffer the effects of health problems on life satisfaction. Emotion-oriented coping (i.e., becoming angry, minimization of the threat, or resignation) has been found to be associated with lower levels of life satisfaction.

Although researchers have explored the relationship between physical health and life satisfaction, the relationship between psychological and cognitive health and life satisfaction remains largely unexplored. Several studies have suggested that psychological well-being (e.g., happiness, lack of depression, positive self-esteem) is positively associated with life satisfaction. With respect to cognitive functioning, even a mild decline may represent a substantial loss of capacity and may diminish overall life satisfaction, though ways may be found to positively adapt to these circumstances. Yet people with cognitive impairments or who take medications that interfere with cognitive functioning are often excluded from studies of life satisfaction. Such sampling practices imply that constructs such as life satisfaction are unimportant for persons with cognitive impairments, or that persons who are cognitively challenged are unable to make sense of or express their perceptions, experiences, and feelings. Nonetheless, recent evidence suggests that cognitive functioning is positively related to life satisfaction.

Financial Satisfaction, Security, and Strain

Overwhelming evidence from both cross-sectional and longitudinal studies suggests that adequacy of income, especially satisfaction with financial security, plays an important role in the life satisfaction of older adults. Wealthier, older adults in a number of countries report higher levels of life satisfaction than individuals experiencing financial strain. Financial problems appear to be a much more important factor

in the well-being of older adults than younger adults, and of older men than women. Socioeconomic status in general appears to be a more important predictor of satisfaction for Whites than for African Americans, and for North Americans in comparison to other national groups. Preliminary evidence suggests that older adults who utilize the life management strategies of selection (choosing specific focused goals and opportunities) and optimization (maximizing the use of their internal and external resources to achieve these goals) experience financial strain to a lesser degree and, consequently, have greater life satisfaction.

Education and Employment/Occupational Status

Evidence for the influence of education and employment status on life satisfaction is inconsistent and relationships tend to be weak, often disappearing when other factors are controlled. Some researchers have found that the relationship between education and life satisfaction differs for various age groups. Others have found that education may be more important to non-White population groups. Although some research suggests that education may play a more important role for women than for men, the opposite has also been found. Education likely has an indirect effect on life satisfaction through its influence on such things as retirement plans, current financial difficulties, and satisfaction with finances as well as perceived health. There is also some suggestion in the literature that the primary advantage of education accrues to those who finish high school and not from further participation in higher education or lifelong learning. Lower educational attainment, besides negatively impacting occupational opportunities and income, is thought to contribute to stable levels of negative affectivity over the life course, which then has an adverse effect on health practices and expectations regarding satisfaction later in life.

Employment status appears to be more strongly related to life satisfaction than to occupational status. Employment continuity has been found to be the most important factor, after health, in assessments of both present and future life satisfaction. Older workers, both male and female, exhibit higher life satisfaction than homemakers or retirees. Being employed part-time is positively associated with life satisfaction among the urban elderly, and involvement in volunteer work has been found to positively influence life satisfaction among community-living elderly persons by enhancing available social support. Nonetheless, the relationship between employment status and life satisfaction tends to be weak and present among only specific groups of older people in the population. For instance, employment status has been found to be more important to life satisfaction for middle-aged women than for older women. However, it is unclear whether this difference holds for men. Past patterns of employment and homemaking do not appear to be related to current life satisfaction.

Age

Early studies found weak negative correlations between age and life satisfaction. However, once other variables associated with aging (e.g., declining health, decreasing financial resources, widowhood, loss of friends, and decreased activity) were introduced, the relationship between age and life satisfaction disappeared. Longitudinal studies tend to demonstrate the stability of life satisfaction over time, though some studies suggest a peak at age 65 with a subsequent gradual and very moderate decrease. When asked to assess the most satisfying decades of their lives, a minority of older adults chose decades during the period of old age. However, the pattern of life satisfaction over the life span is complex and may vary significantly as a function of gender. Further, although different age groups may show similar life satisfaction scores, there may be important qualitative differences among them in the factors that affect life satisfaction. For example, the factors that contribute to the life satisfaction of older adult women have been found to be different from those that contribute to the life satisfaction of middle-aged women.

Gender

Few consistent patterns in life satisfaction can be attributed to gender alone, and the life satisfaction of widows and widowers has not been found to differ. When direct relationships are found, they are generally weak and disappear when other variables are controlled. For example, in a number of populations studied, women had lower educational attainment, less favorable employment opportunities, and lower financial satisfaction, which, as already noted, are associated with lower life satisfaction. However, gender differences may interact with other factors such as race, socioeconomic status, and age. Much work is still needed to determine how these variables interact with and influence life satisfaction.

Marital Status

Marital status appears to be more strongly related to life satisfaction for older adults than for younger adults. Married older adults typically have higher levels of life satisfaction than non-married groups.

Many studies, however, combine for analysis never-married, widowed, divorced, and separated older adults despite the fact that never-married older adult women have been found to report higher life satisfaction scores than widowed women. Never-married older women may have greater involvement in careers in comparison to widows, and this career involvement may account for some of the differences in life satisfaction attributed to marital status. Being married provides social support and companionship that enhance life satisfaction, and older adults who are married typically have higher financial satisfaction and health, which also are associated with higher life satisfaction. Loss of a spouse during old age is associated with a decline in life satisfaction, particularly for men, and older adults who get married appear to have higher levels of life satisfaction. When considering the relationship between marital status and subjective well-being, researchers have not examined the influence of the quality of the marital relationship on life satisfaction.

Leisure Activity, Social Interaction, and Community Involvement

Positive relationships between leisure activity patterns and the life satisfaction of older adults have frequently been found. In fact, some research has suggested that activity levels may be better predictors of life satisfaction than health and income. Frequency and diversity of leisure participation show a stronger relationship with life satisfaction than amount of time spent participating, particularly for those activities that enhance opportunities for self-determination, competence, and challenge. The negative impact of declining health with age on frequency and diversity of activity participation can be offset by the maintenance of high levels of leisure satisfaction through continued participation in a few highly valued activities. Activity levels and hence life satisfaction also may be indirectly or directly influenced by such factors as income, health and functional ability, education level, perceived social competence, and opportunity.

Participation in some activities is associated more strongly with life satisfaction than participation in others. Social, outdoor, and sports activities have been shown to have the strongest associations with life satisfaction, and hobbies the lowest. Engagement in active leisure pursuits has been found to act as a stress coping resource for older adults who are caregivers. Formal activities such as voluntary association memberships also show a positive relationship to life satisfaction for older adults. Nonetheless, the types of activities that are significantly related to life satisfaction have been found to vary by age. Researchers have found that sports, travel, and outdoor activities were the most important predictors for those 55 to 64 years old. Involvement in community organizations, culture and art activities, and travel were the most important activities for young older adults (i.e., 65–74 years). Home-based activities and informal social activities were the most important contributors for those over 74 years of age.

Research has demonstrated the importance of social activities, networks, and support for life satisfaction among older adults. There is evidence that social involvement is more important to older adults than younger adults. For example, social involvement appears unrelated to life satisfaction among those aged 40 to 54 years but is an important positive factor in the life satisfaction of older adults. Life satisfaction appears higher for people with larger social networks and who participate in them more frequently. This finding is particularly true for older adults with disabilities. The quality of social interactions has been found to be more important to life satisfaction than objective factors such as the frequency of contacts. Further, it has been suggested that spending time with family, particularly a spouse, may be more related to global life satisfaction, whereas spending time with friends may have a strong influence on immediate happiness and affect. Again, differences in these relationships have been found among various groups of older adults. For example, social support may be far more important to the life satisfaction of widowed older adults than the never-married.

Role Loss

Older adults who experience greater amounts of change and role loss in their lives have been found to have lower levels of life satisfaction, though this association may be stronger for men than women. Supporting the activity and continuity theories, much of the research suggests that role consistency, particularly a continued sense of usefulness in old age, is related to life satisfaction, as is the number of roles occupied. Participation in social roles has also been found to have a deleterious effect on life satisfaction if more important or central roles engender stress.

Personality and Coping Styles

Research on the links between more enduring dispositions such as personality differences has only just begun to be reported. Neuroticism and extraversion have been found to be positively and negatively correlated with life satisfaction, respectively. Competence and achievement motivation, which are stable

individual differences, are positively correlated with life satisfaction, as is the capacity to experience intrinsic satisfaction in leisure activities.

Coping style, the typical strategies with which people respond to negative external events, also may affect life satisfaction. Empirical studies indicate that coping style, much like stable personality traits, changes little during adulthood. The evidence suggests that there are few significant age-related differences in overall level of coping effectiveness. The influence of coping styles on subjective well-being among older persons has not received much attention. Among older patients with cancer and orthopedic pain, coping style is significantly related to quality of life, even after accounting for the duration and severity of illness. Passive and emotion-focused coping strategies are associated with negative responses to physical illness among older patients. Perceived control and health locus of control have been found to be indirectly (through their influence on activity/exercise levels) and directly related to life satisfaction. Higher self-efficacy in a number of areas of functioning predicts life satisfaction among widows and widowers, though the important domains for men were financial, instrumental, and health. For women, the important functional domains of life in which higher self-efficacy contributed to life satisfaction were interpersonal, emotional, social, and spiritual.

Race, Ethnicity, and Cultural Differences

Race has been found to be more strongly related to life satisfaction for middle-aged compared to older adults. Some studies suggest that older African Americans have significantly higher levels of life satisfaction than older Whites. Others have found the opposite. It has been suggested that race differences in life satisfaction may be better explained by the influence of socioeconomic factors (i.e., educational attainment, economic retirement planning, present financial circumstances). Alternatively, Black and White American life experiences may vary, and, therefore, the predictors of life satisfaction may differ by race. For example, some research suggests a significant negative relationship between race-related stress (i.e., due to racism) and life satisfaction. Social support and integration appear to be important determinants of life satisfaction for Black Americans. Religious participation and religiosity have also been found to be more important contributors to life satisfaction for Blacks than for Whites. In addition, there may be cultural differences in the factors that influence life satisfaction when North Americans are compared to other cultures. For example, family and having love and affection appear to be more important contributors to life satisfaction next to health for West Germans compared to North Americans. More research on aging and life satisfaction is emerging from East Asian countries; however, little cross-cultural research has been reported in which the mechanisms or factors underlying similarities and differences are explored.

Assessment and Prospects

Overall, the research demonstrates that subjective rather than objective indicators are better predictors of life satisfaction. This finding in part may be due to common method variance, that is, to similarities in the ways in which life satisfaction and the subjective indicators used to predict it are measured using paper-and-pencil self-report measures. Also, findings using subjective and objective indicators of the same phenomena do not always agree, as suggested by research in which both subjective and objective measures of the same predictors have been employed. For example, the link between the qualities of the physical living environment and life satisfaction has been examined. The relationship appears to differ depending on whether the indicators are objective assessments or subjective perceptions of these environments. Clearly, researchers need to examine the factors that mediate the relationship between the objective conditions of people's lives and their perceptions of the quality of those conditions. After all, interventions to improve the quality of life of older adults are typically aimed at changing objective living conditions. We should know how changes in these conditions translate into perceptions of satisfaction and quality of life.

Although most of the life satisfaction research has been cross-sectional, longitudinal studies are being employed more frequently, and modeling and trend analyses are being employed to explore changes in life satisfaction over the whole life course as well as the latter years of human life. These approaches are an important step if the determinants of life satisfaction over the life span are to be successfully examined. Further, in spite of the growth and widespread acceptance of qualitative approaches for the study of human behavior, such studies are still infrequent in research on aging and life satisfaction, though a few studies have been reported. For example, the different factors that married and single older adults associate with life satisfaction (e.g., having something meaningful to do, contentment with present circumstances, marking milestones), the different aspects of daily life that people in various stages of later life find meaningful and satisfying,

and the impact of feelings of generativity on life satisfaction have been examined. The detailed scrutiny that these types of qualitative studies can provide would help to improve our understanding of those aspects of people's lives that contribute to life satisfaction.

Researchers also have begun to investigate the nature of the relationship between global life satisfaction and satisfaction with different domains of life using 'bottom-up,' 'top-down,' and 'bidirectional' models. The top-down approach assumes that global life satisfaction is a dispositional trait or personality characteristic that influences a person's evaluation of satisfaction in specific domains. Bottom-up approaches maintain that global life satisfaction is the sum of satisfactions in various domains. Evidence suggests that relationships between global and domain specific satisfactions are bidirectional; however, they may vary across different types of life domains. This line of research seems to hold some promise.

Another line of research that has emerged in recent years, and that has the potential for application, has focused on the evaluation of the impact of various types of interventions designed to improve the life satisfaction and quality of life of older adults. For instance, studies have examined the impact of health promotion and leisure education programs as well as initiatives to provide opportunities for older adults to become involved in altruistic activities. These types of interventions have been shown to enhance the life satisfaction of older adults under some circumstances.

Finally, most of the aging and life satisfaction research has treated life satisfaction primarily as a dependent variable. A useful strategy might be to treat life satisfaction as an independent variable as well. For example, a 4-year study found that older adults with higher levels of life satisfaction had lower mortality rates during the study period regardless of health status. Also, the relationships between life satisfaction and the various factors that researchers have examined are much more complex than the simple bivariate relationships often examined suggest. Fortunately, research is beginning to be reported that is based on more sophisticated multivariate and trend analyses to determine the variables that are directly and indirectly related to life satisfaction and the direction of such relationships.

See also: Economics: Society; Education and Aging; Ethnicity and Minorities; Leisure; Marriage and Divorce; Self-Regulation, Health, and Behavior; Psychological Well-Being.

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Life Span Theory

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Glossary

Development – The outcomes of the accumulation of experiences and of time-related biological processes that affect behavior and physiology throughout the life span of individuals.

Metatheory – Theorizing about theories. Life span theory is a metatheory in the sense that it involves macro-level integrations and syntheses of observations and theories that bear on the understanding of aging and development throughout the life span.

Personal Control – A person's influence on how events are experienced and how tasks are carried out. For example, one important topic in life span theory is the role of the person's deliberate actions in the selection and implementation of strategies for managing situations and making decisions across the life span.

Plasticity – The extent to which change is possible within an individual. For example, one index of plasticity is the extent to which cognitive or physical functions can be improved by practice or intervention.

Primary Aging – A composite of time-related biological processes that affect neuro-anatomical structures and function, and physiology throughout the body, in all organisms. The effects of primary aging on physiological functions and behavior are universal. The course of primary aging is relatively predictable for members of a particular species. In contrast to disease processes, primary aging is insidious and affects all biological systems.

Psychological Aging – Age-related changes in behavior that are generally the dynamic product of past organism–environment interactions, present organism–contextual transactions, and age-associated changes in brain integrity. Psychological aging includes primary aging, secondary aging, individually controlled trajectories within the ranges of plasticity, and dynamic organism–context transactions throughout life.

Reserve Capacity – The range of effective function that is available to the individual for responding to physical or psychological challenges. The amount of reserve capacity available for restoration of homeostasis in response to challenges and insults (e.g., stress, physical illness) is diminished in the oldest old, but not necessarily in young old adults.

Secondary Aging – A variety of moderating factors that serve to negatively influence the course of development and aging. For example, factors such as stress, trauma, and disease serve to accelerate aging processes.

Introduction

Life span theory is concerned with the description and explanation of how individuals change throughout the life course. The study of human aging from the perspective of life span theory is informed by considering the cumulative influences of experiences and biological events that have already transpired for the individual. Individual development and aging is a complex product of past and current biological and sociocultural influences, and thereby draws on many sources of data and theory bearing on individual change. The study of aging from a life span perspective involves the study of age-related interindividual differences and age-related intraindividual change. Life span theory assumes that development occurs along multiple dimensions and that there are both gains and losses in function along different dimensions throughout the course of life. It is also assumed that the interactions among some biological, historical, and sociocultural influences vary for different dimensions of development and aging at different points in the life span. Particular combinations of influences are known to have either more optimal or more negative consequences in regard to effective functioning than others. It is also assumed that there are age-related interindividual and intraindividual differences in the plasticity of function throughout the life span, and in the extent to which the individual can personally control the course of aging along some dimensions. Advances in life span theory depend on a well-equipped arsenal of research methods, including micro-level, age-comparative studies and macro-level longitudinal studies measuring relations across a wide range of biological, cognitive, personality, and sociodemographic phenomena.

Emergence of Life Span Theory

Life span theory represents a way of thinking about the development of individuals as they change

throughout the life span. The view that development is a lifelong process is probably the most general and the most accepted model in the developmental sciences and gerontology. Theorists and researchers have increasingly recognized the view that development is lifelong and that particular phases or eras of the life span are best understood by looking at them within the context of the entire life of the individual.

Data suggesting longitudinal consistencies or continuities are of special interest to life span theory. For example, archival records of Scottish school children allowed researchers to show a relation between the occurrence of late-onset dementia and lower intelligence test performance at age 11. Similarly, in another study of long-term continuities using archival records, researchers showed a relation between higher linguistic expressive ability in young adulthood and reduced incidence of dementia in later life.

Any phase of development may have its own distinctive characteristics and significance, but there are also similarities and continuities with earlier and later periods of the life span. In fact, one of the important questions in the study of life span development is the extent to which there are continuities and discontinuities across the life span. Life span theory has as its core focus the understanding of development per se, not just the cataloging of the changes associated with selected periods within the life span. For example, life span theorists are interested in how the processes and mechanisms of development in the early years of life are different from the later-life processes.

The life span perspective has stimulated new insights into the nature of human development. Some of the major theoretical advances in the developmental sciences can be attributed to the life span view. But an appreciation of the limitations of the life approach also benefits our understanding of human development and aging. Informal, early, and superficial conceptions of the full course of the human life span reinforced the stereotypical idea of development as mostly gain during the early phases of life and as mostly loss in the later years. Innovative contributions by Charlotte Buehler, Erik Erikson, and others that took issue with the stereotypical view of the life course paved the way for late twentieth century writers, especially Paul Baltes, James Birren, Bernice Neugarten, Matilda Riley, and K. Warner Schaie, to make major advances in the conceptualization and application of life span theory. In the early twenty-first century, life span theory has had a positive impact on the science of gerontology by aiding the correction of negative stereotypes associated with particular age periods, such as overly pessimistic views of aging and the elderly. It is anticipated that the life span approach will continue to evolve in light of new observations and theory-building efforts in the developmental sciences and gerontology.

What is Aging?

The term development refers to the accumulation of experiences and the consequences of time-related biological processes that affect behavior and physiology throughout the life span. For individuals attaining normal longevity, development in the later two-thirds of the life span is about aging. Primary aging refers to a composite of time-related biological processes that affect neuro-anatomical structures and function, and physiology throughout the body, in all organisms. Many of the outcomes of these processes are so predictable that they seem controlled by a 'biological clock.' One of the major aims of current research in aging is to describe and explain the relations between primary aging and the contexts in which it takes place. A second major aim is to describe and explain the extent to which there is plasticity, reserve, and personal control in development. That is, a distinction can be made between neurogenic and psychogenic age effects. Neurogenic age effects refer to changes in behavior that are largely the result of primary aging, whereas psychogenic age effects refer to effects of behavior on brain function. For example, age-related atrophy in the prefrontal regions of the brain may lead to inefficiencies in recollection and working memory, and reciprocally, long-term selective disuse of effortful cognitive strategies may lead to atrophy of prefrontal regions. A good example of neurogenic effects is the established relation between physical fitness and cognitive and cardiovascular health.

In contrast to the consequences of forms of disease that are relatively abrupt and affect primarily one system or organ, the consequences of primary aging are more gradual, cumulative, and insidious or system-general. For example, there are gradual but inevitable changes in all physiological systems and sensory-perceptual systems. Further, it is well established that the speed of basic processes or operations becomes gradually slower with advancing age and that such slowing has general or broad-reaching consequences for higher-order functions.

Despite the ubiquity and universality of primary aging processes, one of the most remarkable characteristics of human aging is the wide range of heterogeneity in the expression of the consequences of aging. Secondary aging factors such as stress, trauma, exposure to toxins, and disease negatively influence primary aging or neurogenic effects. In addition to interindividual heterogeneity in the

expression of the negative consequences of primary aging, there are also interindividual differences in the interactive effects of aging, health, and lifestyle. For example, studies have shown robust effects of physical fitness training on cortical plasticity and a cognitive vitality. Such benefits are the result of increased blood flow to particular regions of the brain or to increased synaptic interconnectivity in the frontal lobes as a result of cardiovascular fitness. Further, the circumstances and consequences associated with particular events (e.g., DDT use, 9/11, the AIDS epidemic, the Internet) could be distinctly influential in producing interindividual differences for particular birth cohorts.

In addition to large interindividual heterogeneity, there is also considerable age-related intraindividual variability across various dimensions of biological and behavioral function. Individuals become more unique as they grow older, in part because of their particular histories of life experience. During the life course, the repertoire of an individual is shaped by how that person invested time and energy in work and in human relationships. By deliberate selection and circumstance, the developing individual is both a producer and a product of a myriad of developmental influences. The description and explanation of how individuals change as they grow older and how different individuals show different patterns of change with aging are signature characteristics of a life span approach to the study of aging.

The study of aging has as its major goal the understanding of the orderly or regular time-related or age-related transformations that occur in representative organisms living under representative conditions. The main purpose of theory in the study of aging is to provide a context for organizing the available data bearing on the description and explanation of such transformations. Theories serve the process of articulating meaningful patterns from observations that would otherwise be disconnected pieces of a puzzle and hence less meaningful. In the study of aging, theories are frameworks for connecting laboratory research findings as well as informal everyday observations with emerging themes in the field.

The study of aging can be approached in many different ways. For example, aging can be seen as a complex mix of interacting time-linked biological processes, and/or as a sequence of age-ordered sociocultural prescriptions. In gerontology, one of the aims of life span theory is to capture the full range of individual differences in age-related intraindividual change in functions that characterize the older population. Life span theory is usually considered to be a 'metatheory' in that it is a set of themes for approaching the study of development and aging. Basically, life span theory offers a broadened approach to the study of aging.

Characteristics of the Life Span Approach

The characteristics of the life span approach are summarized in **Table 1**.

The notion that aging is multidimensional and multidirectional is one of the basic tenets of a life span orientation to the study of aging. Consistent with evidence suggesting increased interindividual differences with aging in healthy adults, the experience of aging seems to produce cumulative differentiation within individuals along multiple dimensions. The fact that gain, or growth, as well as loss, or decline, can be observed throughout the life course has provided a general framework for researchers to explore some of the positive attributes of aging. For example, the study of the characteristics of wisdom and creativity in late life, the maintenance or continued evolution of exercised cognitive skills and cognitive expertise in the later years, and the emergence of emotional maturity in late life are areas receiving increased research attention. However, efforts aimed at describing the positive aspects and potentials of late life functioning must be objective

Table 1 Summary of the major characteristics of a life span approach to the study of aging

1. Aging is a cumulative, lifelong process.
2. Aging is multidimensional and multidirectional in that there is variability in the rate and direction (gains and losses) of change for different characteristics within individuals and across individuals.
3. There is plasticity and resiliency in function throughout the life span, but less so in very late life.
4. There are age-related differences in the extent to which the individual is or can be active in determining the course of aging along some dimensions.
5. Aging is a product of the interactive effects of neurogenic processes and the historical and sociocultural contexts in which change takes place; the contributions of environmental and biological influences vary for different dimensions at different points in the life span. Some combinations of neurogenic and environmental influences may be uniquely synergistic.
6. The study of aging involves the integration of multiple theoretical perspectives across multiple disciplines and professions (e.g., anthropology, biology, medicine and nursing, psychology, sociology).

and take into account the realities of loss and decline. In their efforts to dispel overly negative views of aging, life span researchers have considered the pragmatics of aging. That is, one line of evidence in support of a more balanced view of aging is based on observations of ordinary lives in progress in real settings in contrast to age comparisons based on standardized tests and measures that are indigenous to youth and insensitive to the unique qualities of older adults. Another line of research evidence in support of a more balanced view is derived from studies that distinguish between the characteristics of normal aging, illness-free aging, and successful aging. Research on successful aging has as one of its aims the identification of the personal attributes and contextual characteristics of individuals who minimize or escape the debilitating consequences of aging and disease. From a gains vs. losses perspective, there is a complex array of human capabilities; some show decline, some improve, and some remain the same across selected time periods. A third line of research leading toward a more balanced view calls attention to the differences between the young old and the old-old, such that the vulnerabilities of very late life are distinguished from the potentials of the young old. The advancement of a balanced view of the potentials and limits of aging is a main theme of life span theory.

Another main theme in life span theory, as illustrated in **Table 1**, is associated with the terms plasticity, reserve capacity, and personal control. Plasticity refers to the potential for intraindividual change. Intraindividual plasticity is evident when there is variability in levels of performance across different kinds of tasks or when there is variability in carrying out the same task at different times or under different conditions. Life span researchers are interested in understanding developmental differences in the gap between observable behavior and underlying competence or potential. It is assumed that the potential for optimization is present throughout most of the life course, but plasticity and reserve capacity are constrained near the very end of the life span, such that the individual is vulnerable to a variety of circumstances associated with mortality at that point. The term reserve capacity refers to the individual's resources for responding effectively to challenging conditions. The term resiliency is similar in its meaning, and refers to a capacity for successful adaptation and recovery in response to stressful life events. Individuals exhibit varying capacities to protect themselves from impairment and insult associated with aging and disease, and to adapt effectively to the demands of stressful situations.

Successful development and aging also involve the ability to deliberately or actively influence the course of one's own development in various ways. Personal control refers to the person's ability to affect how events are experienced or how tasks are carried out. For example, personal control might involve emotional selectivity, cognitive optimization, and strategies for managing situations and making decisions. Personal control is associated with frontal lobe functions such as planning, ordering and sequencing of information, cognitive flexibility, stimulus selectivity and inhibition, and working memory and executive control functions. Control functions are also mediated by interactions between the frontal lobes and other brain regions that are engaged depending on the nature of task. Although there are age-related inefficiencies in the performance of complex tasks, individuals can control task selection and strategies so as to optimize behavior.

The concepts of plasticity and personal control hold promise for improving our understanding of the relationship between aging and behavior. Analogous to cardiovascular function, or muscular efficiency, healthy older adults usually function quite effectively in everyday non-stressful conditions, but their functioning is likely to be impaired under stressful conditions. That is, age-related deficits in behavioral efficiency are most prominent when systems that are critical to maintaining performance are challenged or stressed. The study of reserve capacity is useful for describing the effects of aging on a wide range of functions under stressed conditions. However, studies of reserve capacity and resiliency do not address how development can be enhanced in situations in which there is optimal support.

Another main characteristic of a life span view is the idea that development and aging are continuously and simultaneously influenced by a wide range of neurogenic and social processes. Although it seems trivial to point out that aging has multiple causes, most theories of aging underemphasize the malleable aspects of aging. As previously mentioned, many of the antecedents and consequences of aging are universal and species determined (e.g., graying hair, menopause), whereas other antecedents and consequences of aging are idiosyncratic or cohort specific, culture specific, or specific to a segment of historical time (e.g., happiness, wisdom).

Methods in the Study of Life Span Development

Perhaps one of the most important methodological issues in developmental research involves the

distinctions among age, cohort, and time of measurement as potential sources of influence on development. It is now well known that many observations of age differences in behavior are attributable to cohort factors (influences associated with time of birth) rather than to age factors per se. Cohort factors account for more of the variance than does chronological age in some ability domains. The validity of inferences drawn from cross-sectional comparisons of different age groups is confounded by variability associated with chronological age differences and cohort differences. Further, the validity of longitudinal comparisons across multiple times of measurement is confounded by variance associated with chronological age change and the influences of changing sociohistorical circumstances.

Another important methodological theme in life span theory has to do with the specification and meaning of the age variable. Although age-related change is usually described in terms of years since birth or calendar time, chronological age often does capture or accurately correspond with the course of some time-related phenomena. One theme of the life span approach is to replace chronological age with index measures that more accurately represent the course and underlying sources of time-related or age-related change (e.g., brain imaging measures). Further, the effects of aging on behavior are sometimes irreversible, analogous to the irreversible consequences of chemical or nuclear reactions. The effects of aging on behavior can also be quantitative and continuous rather than qualitative, and reversible rather than irreversible. It should also be noted that markers of elapsed time are insensitive to the meaning of time as a relative and subjective dimension. Indeed, the experience of the passing of 365 days is likely to not be the same at different ages. There are also biological clocks based on biomarkers or measures of physiological time, and social clocks based on the socialization of age prescriptions.

Since age and time are not causes of change per se, an aim of aging research is to identify the mechanisms that are primarily responsible for age-related change. Successful explication of the mechanisms that produce aging would enable researchers to replace chronological age (measure of time since birth) with the real index variables and the real causal variables for which it is proxy. For example, there is some evidence suggesting measures of brain reserve capacity can serve as more accurate measures of the effects of aging than chronological age.

It should also be mentioned that the multicausal and multidirectional themes in life span theory have driven the development of new methodologies and methods for the analysis of multiple antecedents and multiple outcomes across age and time. The life span approach has led to a number of significant advances in the way researchers think about the analysis of change.

Implications for the Interdisciplinary Study of Aging

One consequence of acknowledging the multidimensionality and multicausality of aging is that life span researchers try to be both specialists and multidisciplinary generalists in their outlook. Although a high degree of disciplinary specialization is usually required in order to contribute meaningfully to the advancement of scientific knowledge about aging, life span researchers find it useful to be informed about findings across related specializations. Occasionally, such linkages lead to major changes in how we think about aging processes. For example, the idea that aging consists of multiple antecedent mechanisms and multiple outcomes is now generally taken for granted. Further, from the gains vs. losses perspective, to the extent that lifelong experience contributes to the construction of distinctive systems of knowledge for particular cohorts, the aging individual thinks and acts in ways that expand some opportunities and at the same time restrict other opportunities.

Some of the most significant advances in the study of aging reflect multidisciplinary integrations and inferences drawn from comparisons and contrasts across widely different age groups and cohorts. For example, quantitative work in developmental behavioral genetics has shown that there are unique combinations of nature and nurture that produce synergistic or optimal outcomes for development. Further, much of the variance is shared between genetic and environmental factors, leaving ample room for personal control.

Finally, it should also be mentioned that a life span orientation complements the aims of research and practice in developmental and clinical intervention. How the aging individual compensates for age-related decrements is an important practical theme in life span theory. Some life span researchers maintain a focus on the optimization of aging in everyday situations. Several of the prevailing models of cognitive development in adulthood and aging emphasize such notions as knowledge encapsulation and selective optimization. Some life span researchers also give emphasis to the idea that individuals are active in constructing and controlling their own development throughout the life span.

Summary and Conclusions

In conclusion, life span theory provides a basis for describing both gains and losses associated with aging. Life span theorists give emphasis to the potentials as well as limits of intraindividual change across the life span. Due to a combination of influences, many developmental outcomes are possible for each person: some outcomes are more likely than others, some outcomes can be made more likely, and some outcomes are not possible. The study of aging from a life span orientation gives emphasis to the idea that our understanding of human aging across domains (biological, biomedical, cognitive, social) can be advanced by research that views aging as both a cause and a product of interactions among biological and sociocultural factors across time and age.

See also: Caregiving and Caring; History of Gerontology; Life Course; Research Design and Methods; Theories of Aging: Biological; Theories of Aging: Psychology; Theories of Aging: Social.

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Literary Representation of Aging

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Glossary

Swan Songs – Narratives written when their authors knew that their time on earth was limited.

Overview and History of Literary Representation of Aging

Just as in youth, aging is affected by issues of class, race, gender, health, family dynamics, and genetic good fortune. As we age, we discover how variable later life can be. Some older psychiatrists have compared the stresses of this time of life to those of adolescence. The unpredictability of that stage, they

maintain, is an important marker. Therefore, if writers fail to recognize the sometimes confusing transitions of their older characters' lives, they are most likely engaged in sentimentality or stereotyping.

Why are some portrayals of aging convincing and impressive whereas others are less so? E. M. Forster in *Aspects of the Novel* (1927) distinguished between what he calls flat and round characters. His categories can be applied to depictions of aging. As readers, we hope to be entertained and informed about the human condition. Flat characters, such as Mr. Smallweed, a vicious moneylender in Dickens' *Bleak House* (1852–1853), startle and amuse us, but do not teach us what it feels like to be in the body and mind of an elderly protagonist. To some extent, the ability to empathize with aging characters depends upon the age of the writer. Younger poets, novelists, and playwrights may assume erroneously that the elderly have little potential for emotional growth or the capacity to surprise the reader. Fortunately, some relatively youthful writers have the empathy and curiosity necessary to comprehend and display the complexities of later life. In general, however, by the time most writers reach late middle age, they can more easily draw upon personal experiences – both their own and those of friends and relatives.

In prior centuries the life course was generally shorter than it is today. Until the middle of the twentieth century few writers had productive late years. Still, some remarkable portraits of aging appeared. For example, Homer, who traditionally has been depicted as a blind, elderly bard, presented a range of older characters in the *Iliad*. Nestor, an aging Greek leader, is much too garrulous to be an effective counselor. On the other hand, Priam and Hecuba, Hector's aging parents, respond to his death and the destruction of Troy with great dignity and courage. Aging characters in Greek comedies traditionally were blocking figures, determined to complicate the lives of their youthful charges. That formula also appeared in medieval poetry. Chaucer (ca. 1343–1400), however, presented a range of older characters. These include the vital wife of Bath, who has married five times but seeks yet another husband if luck should be on her side. In contrast, the hapless January in "The Merchant's Tale," the merchant insists, deserves the cuckolding he endures for the sin of marrying a much younger wife.

Of course, characters grew old at an earlier stage of life than they do nowadays, just as their authors felt old at a relatively early age. It is not entirely clear how old King Lear is, for example, when he resigns his throne, but whatever his age, Shakespeare (1564–1616) portrayed his voluntary retirement as premature and even foolish. Despite his many mistakes, however, Lear, like his friend the Earl of Gloucester, matures dramatically in the course of the play. Beset by his enemies, he yet endures to achieve a dignity that suffering had taught him.

Written at about the same time *King Lear* was composed (1608, the first quarto), Cervantes published sections of *Don Quixote* between 1605 and 1615. The novel begins as a satire on honor and chivalry. Quixote, the elderly knight, has addled his brain by reading too many romances, tales that were very popular at the time the novel was written. After several adventures, however, Quixote begins to develop heroic qualities. Readers gradually become very fond of the old man, despite the absurdity of some of his adventures. Cervantes makes us almost wish that the world were more like the one Quixote imagines.

The change in Quixote's reception is similar to that of Shakespeare's Falstaff. This famous aging character was also conceived to satirize the concept of honor. In *Henry IV,* Part I (1597) Falstaff organizes outings and encourages Prince Hal and his retinue to drink, gamble, and wench, all diversions from the duties of valorous warfare. A complication in audience reaction comes when Hal rejects Falstaff in *Henry IV*, Part II (1598). Of course, casting out the old knight is a sign that the prince has repudiated his rebelliousness and is now ready to become king. Nonetheless, he dismisses Falstaff in such a cruel fashion that playgoers sympathize with the plight of the foolish old knight. His death is reported in *Henry V* (1599), but he also appears in *The Merry Wives of Windsor* (1597–1600) as Sir John in love – absurdly so. The dates are approximate.

In the nineteenth and mid-twentieth centuries, some poets and novelists admire older people almost as if they long for a premature old age. For example, Wordsworth (1770–1850) not only wrote with sympathy and affection about the ancient leech-gatherer, but also insisted in "Tintern Abbey" (1798) and "Intimations of Immortality" (1807) that old age is a richer stage than youth. Given the early deaths of Wordsworth's parents, one can speculate that melancholy rather than enthusiasm accounts for the youngish poet's insistence on the compensations of age. Unfortunately, the poetry of Wordsworth's middle years lacks the spontaneity of his early verses.

Some poets and playwrights of the late nineteenth and twentieth century have also created impressive portraits of aging figures. The plays of Henrik Ibsen (1828–1906) and Anton Chekhov (1860–1904) feature some arresting older characters, such as in Ibsen's *The Master Builder* (1892) and in Chekhov's *Uncle Vanya* (ca. 1899–1900) and *The Cherry*

Orchard (ca. 1904). At 68, William Butler Yeats (1865–1939) published several poems about aging. One is "Crazy Jane Talks To the Bishop" (1933). Jane is a ragtag old woman who talks back to the bishop, a disapproving authority figure. An especially moving short poem is "After Long Silence" (1933), a reunion of lovers in old age, who conclude that physical decline brings wisdom; youthful love lacks experience of the world. Moving on to recent times, poets Virginia Adair (1913–2004) and Stanley Kunitz (1905–2006) have published in old age. Adair issued her first collection, "Ants on the Melon" (1996), at 83. Many of the poems were written earlier, but after her husband's suicide she had put aside thoughts of publication. After a long and successful career, Kunitz published a collection at 90. The collection, "Passing Through: The Later Poems, New and Selected" (1995), won the National Book Award. On the whole, however, poets and playwrights have written less about aging than recent novelists and short story writers.

Nonetheless, the influence of poets such as Wordsworth can be found in some stories and novels. In the nineteenth century, two women writers combined a sympathy with the aged with an understanding that women need to be tough to survive. Maine author Sarah Orne Jewett (1849–1909) wrote with nostalgia about elderly women and men in *A Country Doctor* (1884) and the days of ship captains and their wives in *The Country of the Pointed Firs* (1896). In *The Country Doctor*, the old doctor helps his orphaned young ward find her way as a woman physician. Fourteen years later, in *The Country of the Pointed Firs*, Jewett described a once-active seafaring town filled with elderly folk who yearn for the days of their youth. Fortunately, the sentimentality is leavened by Jewett's careful observations of the dialect and behavior of each character. Even more tough-minded and equally observant are the short stories of Massachusetts writer Mary Wilkins Freeman (1852–1930). Her collection, *A New England Nun and Other Stories* (1891), highlights the plight of aging women, marooned in New England. An economic decline had caused younger folk to desert for more promising areas of the country. Despite their poverty and lack of power, some of these elderly women surprise the rest of the town folk by insisting that their lives matter, too.

A more modern example of the Wordsworth phenomenon can be found in the novels and journals of May Sarton (1912–95). In her youth and middle age, Sarton idealized strong older friends or others like those whose lives she depicted in her novels, such as *Mrs. Stevens Hears the Mermaids Singing* (1965), published when Sarton was 53. Unfortunately, Sarton's old age did not follow the desired script. Given her ill health following her stroke in 1986, it is not surprising that Sarton created a final protagonist, Harriet Hatfield (1989), who at 60 was younger and spryer than the 77-year-old author herself. Despite disability and depression, Sarton kept on producing journals, but as gerontologist Harry Berman has pointed out, one sees more unpleasant glimpses of the sacred monster of melancholy as Sarton aged.

Categories of Literary Representations of Aging

Besides the preceding works, fictional narratives can in general be divided into various categories depending on how aging is depicted. The categories are the following: idealized parent figures; midlife crisis and opportunity; late-life love; grandparents; disability and degrees of decline; retirement; retirement communities; life reviews; death, dying, and rituals of grief; and swan songs.

Idealized Parent Figures

Idealized mothers and fathers abound in early twentieth century modernist works, as well as in more recent fiction. In his early 30s, English novelist E. M. Forster (1879–1970) created an enigmatic older woman, Mrs. Wilcox, in *Howards End* (1910). Energetic, powerful males surround her. In the end her spirit dominates, however, for the ill health and misjudgments of the men diminish their control. Fourteen years later Forster created Mrs. Moore, a mystically powerful old woman, in his masterpiece *A Passage to India* (1924). Mrs. Moore has the ability to reach across barriers of ethnicity, religion, age, and class when the other characters find these chasms unbridgeable. When in her mid-40s, Virginia Woolf (1882–1941) wrote *To the Lighthouse* (1927), which contains moving portraits of her father and mother, the latter having died when Woolf was in her teens. Like Mrs. Wilcox and Mrs. Moore, Woolf's Mrs. Ramsay is the guiding spirit of the household in death as well as in life.

Later in the twentieth century, strong male figures emerged. During the civil rights era, Harper Lee (b. 1926) published *To Kill a Mockingbird* (1960). Her hero is a middle-aged lawyer, who willingly defends a black man unjustly accused of raping a white woman. In 1991, English novelist Pat Barker (b. 1943) published the first volume of her Regeneration trilogy of World War I (1991–95). Although many of her young characters are important, the emotional center is W. H. R. Rivers, the psychiatrist

who in real life had treated World War I officers suffering from shell shock. He is 53 years old and his patients are in their 20s, so they tend to think of him as a father figure.

Midlife Crisis and Opportunity

Willa Cather's (1873–1947) *The Professor's House* (1925) is in many ways the archetypal midlife crisis novel. Professor St. Peter, like Cather herself at the time of publication, is 52. He has successfully completed his life's work, having written eight volumes of *Spanish Adventurers*, a prize-winning work. Depressed by thoughts of the future, he mulls over the past and the death of his favorite student, the brilliant Tom Outland, who was killed in World War I. Mourning the lost vitality of his youth, St. Peter realizes he no longer finds his wife and daughters of much interest. After talking to a down-to-earth seamstress at the novel's end, however, he gathers the strength necessary to return to the life that he no longer desires.

In contrast to Cather's melancholy work, English academic novelist David Lodge's (b. 1935) *Therapy* (1995) and Scottish writer Alexander McCall Smith's (b. 1948) seven novels about Botswana (1998–2006) offer more hope to their middle-aged protagonists. Lodge's hero, Laurence Passmore, at 58 suffers from an unexplained depression. As his situation deteriorates, he recalls his first girlfriend, Maureen, out of his adolescent past. Eventually he finds her on a pilgrimage to Santiago de Compostela. The two complete the journey, and although she returns to her husband, their continued friendship in London brings him some degree of peace.

McCall Smith's series about the No. 1 Ladies' Detective Agency features older women and men who are busy living active lives in Botswana. Precious Ramotswe, a middle-aged woman of size, decides to start her agency, drawing upon her knowledge of human nature and upon Clovis Anderson's *Principles of Private Detection*. Not only does she solve the problems brought to her by troubled women and men, but in time she is also able to confront some of the ghosts of her past. After marrying the kindly Mr. J. L. B. Matekoni, a skilled but sometimes depressed automobile mechanic, she finds the courage to outwit Note, the man who abused her when she was young and vulnerable.

Late-Life Love

Unlike Chaucer's *The Merchant's Tale*, in which the aging January is punished for his lust for the nubile May, Vita Sackville-West and Jon Hassler showed sympathy for an older person's desire for love. English novelist Sackville-West (1892–1962) wrote about the short widowhood of Lady Slane in *All Passion Spent* (1931). Her husband, the first Earl of Slane, dies at 94 while she is merely 88. Having done her duty to her husband and children, she decides to move to Hampstead, near the Heath, and away from her family. This freedom allows three old men to fall under her spell. For the first time since girlhood, she is able to bask in the approval of her landlord, the builder who repairs the house, and Mr. FitzGeorge, a friend of her son Kay.

In his early 50s Jon Hassler (b. 1933) wrote compassionately about Miss Agatha McGee in *A Green Journey* (1985). Miss McGee is a Catholic of the old school and is most dismayed by the changes of ritual first brought about in Vatican II. A school teacher in her late 60s, she starts a correspondence with James O'Hannon, believing him to be an Irish school teacher about her age. For many years a formidable presence in her community, Miss McGree discovers that she yearns for love and understanding. Hassler shows great respect for the intelligence and strength of the elderly woman and for O'Hannon, who, to Miss McGee's dismay, turns out to be a priest. In a sequel published eight years later, *Dear James* (1993), we learn that Agatha has been devastated by his deception. Fortunately they reconcile. Her parish priest approves. He realizes that these two elderly people have much in common with Saint Francis of Assisi and Clare, being passionate but completely celibate. At the novel's end, Miss McGee feels reconciled to her community and capable of living on her own once again.

Grandparents

Several narratives highlight the lives of grandparents. Five years before *Regeneration* (1991), Pat Barker published *The Century's Daughter* (1986), about the last days of an 84-year-old woman. In many ways it was a tribute to her grandmother, who, along with her grandfather, had bought her up in Yorkshire and encouraged her to get an education.

In two short stories Peter Taylor (1917–94) and Gish Jen (b. 1955) emphasized the differences between generations. "In the Miro District" (1977), published when Taylor was 60, depicts a grandfather and grandson who can find no common ground despite the assumption of the boy's parents that they will be friends. In fact, the grandson seems determined, as one critic has pointed out, to debase his grandfather's space by having sex with his girlfriend in the grandfather's bedroom. That act of ritual desecration convinces the old man that he can no longer

stave off the ravages of age. Instead, he moves in with his daughter's family and becomes like all the other Confederate War veterans, who dress up in uniform and accept repeated promotions in rank.

In Gish Jen's "Whose Irish?" (1999), a 3-year-old Americanized half-Irish granddaughter provokes her Chinese grandmother and babysitter into spanking the child in a vain effort to tame what the grandmother considers to be wild and un-Chinese behavior. The outraged parents force the old woman to leave their house. No reconciliation takes place, but, the Irish paternal grandmother asks the Chinese one to move in with her to provide some feminine company. Middle-aged herself, Jen employs a detached and wry tone.

A remarkable story about grandparents is Gloria Naylor's (b. 1950) *Mama Day* (1988). Naylor's intergenerational novel has occasional touches of magic realism. It takes place on an island offshore of Georgia and South Carolina, inhabited entirely by African Americans and ruled by Miss Miranda "Mama" Day. The story begins when Mama Day is in her 80s and ends when she is almost 100. The Day family descends from Sapphira Wade, who, they remember, was never a slave. In the third generation three daughters experience tragedy. As a result of untimely deaths, Miranda and her sister Abigail have but one grandchild between them to rescue from premature death, Ophelia, also known as Baby Girl or Cocoa. Mama Day, who is a midwife and local herbalist, is blessed and cursed with second sight. The townspeople of all ages turn to her whenever they are in trouble, despite her advanced age.

Besides these novels, there are three additional intergenerational immigrant novels with touches of magic realism, written by young women in their 20s and 30s. Hiromi Goto's (b. 1966) *Chorus of Mushrooms* (1994) features a Japanese grandmother who lives in Alberta but has learned no English. Nonetheless, she becomes very important to the granddaughter once she leaves the family's house for an epic journey. Cristina Garcia's (b. 1958) *Dreaming in Cuban* (1992) portrays a close relationship between a Cuban grandmother and her Cuban American granddaughter. Despite Castro and the distance of time and space, the two speak to each other for many years until at last the granddaughter thinks she has enough of her forebear's story to continue on her own. The heroine of Edwidge Danticat's (b. 1969) *Breath, Eyes, Memory* (1994) also has a close relationship with her Haitian grandmother. For many years the grandmother and aunt take care of Sophie Caco in Haiti. Her mother Martine moves to New York in the vain effort to forget how she was raped by a *Tonton Macoute*, one of dictator Duvalier's paramilitary thugs. Fortunately for Sophie and her infant daughter, the extended family creates a sustaining community of women and rituals that help Sophie recover from the pain of ensuing loss.

Disability and Degrees of Decline

Disabilities in the following novels include the effects of ill health, depression, stroke, and dementia, but the characters with the disabilities display great energy. Anzia Yezierska (ca. 1881–1970), an immigrant novelist from Eastern Europe, wrote popular novels in her 30s about aspiring immigrant women. In her 60s she wrote an autobiography with more than the usual amount of fictional elements. She composed "The Open Cage" (1979), a posthumously published story, in the 1960s when she was in her 80s. In it, an elderly woman energetically complains about failing eyesight, faulty memory, and impoverished surroundings. Despite the problems of old age, Yezierska's narrator identifies with a bird who accidentally flies in her window. She celebrates when the bird is released to the wild, but mourns that she, alas, must return to her room, a place of confinement for the aged, marked by poverty and loneliness.

An even earlier novel about disability is *Mrs Palfrey at the Claremont* (1971), composed by English writer Elizabeth Taylor (1912–1975). Mrs. Palfrey is an elderly widow who suffers from arthritis. She lives in an inexpensive hotel with other old people but dreads the thought of a nursing home. She knows, however, that she will have to move against her will if the arthritis becomes crippling. Taylor had the gift of close observation and empathy. She took seriously the lives of her older characters and treated their problems as worthy of attention.

Alison Lurie's (b. 1926) *The Last Resort* (1998) combines social satire with a hopeful attitude about the capacity of some characters to start their lives afresh in midlife. This amusing intergenerational novel is set in Key West, which is inhabited by elderly artists, the young and middle aged, gays and straights. Wilkie Walker, an aging writer and naturalist, is convinced that he will soon die of cancer. To avoid that fate he attempts to drown himself, but every effort fails for absurd reasons. Although he has had a successful career, in old age he has become a complaining egotist. Other older characters are more stoical than Wilkie. Not surprisingly, his younger wife, Jenny, who has served as his acolyte for many years, finds serving a withdrawn old husband less than compelling. She discovers the pleasures of genuine affection in her new friendship with Lee, an attractive lesbian.

In his early 40s Brian Morton (b. 1955) wrote *Starting Out in the Evening* (1998), a novel with a

compelling portrait of an artist in old age. Leonard Schiller in his 70s is struggling to write yet another novel, despite the lack of interest shown in his earlier work. A young student seeks him out, hoping to write a master's thesis that might rehabilitate the old novelist; Schiller grants her interviews. Toward the end, however, the novel takes an unexpected turn. The thesis writer shows little respect for Schiller's later work, and the old man has a stroke, leaving him in need of caretaking. His feckless and immature middle-aged daughter proves capable of meeting the challenge. The old man returns to his unfinished novel while accepting the necessary assistance of his daughter and her boyfriend, both of whom prove equal to the task.

Two experimental novels are J. Bernlef's (b. 1937) *Out of Mind* (1984) and Howard Engel's (b. 1931) *Memory Book* (2005). Bernlef (Hendrik Jan Marsman), a Dutch novelist, wrote about the onset of Alzheimer's from the point of view of the sufferer, a Dutch immigrant to America. In the beginning, 71-year-old Maarten seems somewhat absentminded. His thoughts are represented by complete sentences and paragraphs. His decline, however, is very swift. It is not long before his wife, Vera, decides to hire another woman to help her manage her husband. To Maarten it seems as if Vera has withdrawn from him, and his condition deteriorates dramatically. By the time he is put into a nursing home, he has no idea where he is. He thinks he is in Holland during World War II under German occupation. Toward the novel's end the paragraphs are short, the sentences full of ellipses, and the ideas disconnected. Howard Engel, a Canadian detective story writer, suffered a stroke in 2001 that caused alexia, the inability to read. Nonetheless, in 2005 he published *Memory Book*. In it his middle-aged sleuth, Benny Cooperman, experiences the same kind of stroke. Not surprisingly, his disability complicates his ability to solve crimes, but, like his author, he finds a way of coping.

Retirement

Problems and advantages of retirement are featured in several novels. When in her early 60s English novelist Barbara Pym (1913–1980) wrote *Quartet in Autumn* (1977), which was shortlisted for the prestigious British Booker Prize. When she began a draft of the novel, she was facing early retirement herself, having had a stroke that followed a mastectomy. For several years she had refused to quit her job until her doctor insisted on it. Fortunately, her reality turned out to be far happier than she had anticipated. The characters in the novel face some of the health problems and isolation that she had feared, but all but one find it possible to renew their friendships and find muted pleasure in their lives.

Jon Hassler at midlife wrote a comic novel about premature retirement, *Simon's Night* (1979). Simon is an emeritus professor of English who becomes depressed and loses confidence in himself when at 76 he begins having some memory problems. He decides that he is not fit to take care of himself and moves into a small retirement home. So little stimulation exists in the home that he is warned by a young doctor to leave as soon as he can. The home is a soul destroyer, but Simon turns out to be surprisingly resourceful.

Tony Hillerman (b. 1925) has been writing detective stories about a Navajo Police lieutenant, Joe Leaphorn, for many years. In recent novels Joe has retired from the force, but whenever a knotty problem arises, young Sergeant Jim Chee needs his help. At nearly 80, Hillerman published *Skeleton Man* (2004), in which once again Joe Leaphorn plays a role. In fact, Leaphorn's telling of the story provides its narrative frame. Leaphorn reacts wryly when he revisits the station that he had run for many years only to discover that few remember him. Hillerman is hardly the only aging detective story writer still active. On May 15, 2005, the National Public Radio program "All Things Considered" aired a piece on aging writers of detective stories. As writers, such as Elmore Leonard and Tony Hillerman, are aging, their detectives are aging with them.

Retirement Communities

Two novels describe very different retirement communities. A youthful Gregg Kleiner wrote a lively fantasy about aging solidarity in *Where River Turns to Sky* (1996). The hero, George Castor, at 80 finds out that his old friend Ralph has died alone in a nursing home while George was off fishing, despite having promised that he would not desert his friend. George hates the home for its lack of humanity. In his anger he buys a big house in town, paints it red, and spirits some of the inmates out of the home to join him in the effort to make a genuine community. The group grows robustly and survives the death of some of the residents, including that of George himself, who has cancer. In the end new people join the old residents, and the survival of the group is assured.

James Michener's (1907–97) *Recessional* (1994) is based on solid research. It was published when he was 87 years old and had already published 38 books. *Recessional* takes place in a retirement center in Tampa, Florida, called the Palms. Most of the residents are rich, for the fees are steep. The plot has elements of soap opera. Just about every possible

scenario unfolds. By far the biggest headache for Andy Zorn, the young director, has to do with end-of-life issues. Some residents lack valid advance directives and to his dismay are kept alive artificially on life support. Unlike Kleiner, Michener does not suggest that the Palms is a place of horrors. The residents he describes are vital individuals whose life stories are of interest.

Life Reviews

Characters in five novels reconnect to the past in different ways. The earliest of these is John P. Marquand's (1893–1960) *The Late George Apley* (1937). In its time the novel was regarded as an amusing satire, but it is far sadder than that. The narrator describes a man who is reared to conform. In youth he longs to marry an Irish woman named Mary Monahan, but his parents would have none of it. Instead, he marries Catharine Bosworth, whom he does not love, and as a result his life has many dreary moments. When he knows he is gravely ill, for a moment he reflects honestly upon his life. He realizes that pleasing others has made it impossible for him to recognize his own true feelings. Even so, he fails to understand that his children have moved far away to avoid having to follow in his footsteps.

Wallace Stegner (1909–93) published *Crossing to Safety* in 1987. It is a compelling story of four friends who meet in youth but maintain their friendship into the beginning of old age. Like many novels of life review, much of the plot reconstructs their early lives. After many years of friendship, some of it by long distance, the Morgans, who are in their 60s, are called back to the Lang family compound in Vermont. Charity Lang, who in many ways has dominated the lives of the four, is dying of cancer and wishes to orchestrate her end, just as she has tried to control the rest of her life. Unfortunately, Charity's desire to mastermind her final days pains her husband deeply because it represents yet another vote of no confidence in his manhood. The four renew their friendship, but their crossing is perilous.

Peter Pouncey's (1938) *Rules for Old Men Waiting* (2005) describes an 80-year-old man who is grieving the loss of his wife and somewhat passively awaiting his own death. He recognizes physical symptoms that need medical care, but instead of taking charge of his life, he uses his flagging energy to construct some fascinating stories. These narratives combine elements of his own life, including his service in World War II, with a fictional story of trench warfare in World War I. The war plot, which features a villain, is an outgrowth of MacIver's (and Pouncey's) research in military history. As the novel progresses, the reader begins to realize that the villain's own uncontrolled emotions have their counterpart in MacIver's lifelong struggle with anger.

The final two novels break new ground in the genre of life review. At age 80, English novelist Stanley Middleton's (b. 1919) *Necessary Ends* (1999) chronicles a year in the life of an 81-year-old man. Like several other older writers in recent years, Middleton is not afraid to discuss death and dying, but perhaps surprising is his interest in old age sex and desire. Although Samuel Martin thinks a lot about the past, he is such an outgoing person that he quickly makes new friends during his first year in a seaside village. He begins to have a surprising relationship with Alice Jeffreys, a woman in her 60s, whose husband has cheated on her repeatedly. Alice controls their relationship, but permits him liberties. In one wonderfully orchestrated scene in bed, the old man strokes her hair and touches her breasts while she continues to discuss her musical interests in vivid detail. Sam feels completely rejuvenated for a time. At the novel's end, however, a new acquaintance of Sam dies unexpectedly. The death saddens him in unexpected ways. He has little fear of his own demise, he muses, but the death of friends shatters his self-confidence.

Marilynne Robinson (ca. 1944) won the 2005 Pulitzer Prize for *Gilead* (2004). John Ames, a preacher in Kansas, is facing death from heart disease at 76. Because the novel is set in 1956, his doctors can do little to extend his life. Recognizing that his beloved son is only 6, he writes an extended letter to the boy about his family history and his thoughts about life in the present. The novel is unusual for its theologically serious discussion of religion and the religious life. Moreover, Ames's life review incorporates unresolved feelings of jealousy and sadness about his imminent death. Like the best of these novels on aging, *Gilead* appeals to our intellect and our emotions.

Death, Dying, and Rituals of Grief

Death is described as a natural process, with little pain and unhappiness, in Willa Cather's *Death Comes to the Archbishop* (1927). Like Sarah Orne Jewett's dying characters, the archbishop suffers a short decline and peaceful end. Contemporary novels rarely have characters slip away so easily, even in situations in which the figure is not hospitalized. Memoirs that confront death with all its horrors include Madeleine L'Engle's (b. 1918) *Two-Part Invention* (1988), published when she was 70. In her earlier memoir, *The Summer of the Great-Grandmother* (1974), L'Engle's family takes care of her 90-year-old mother in order to keep her out of a nursing

home. The demented old woman's dying exhausts the family, even though they willingly have taken on the burden. In contrast, 14 years later L'Engle's husband, Hugh Franklin, develops bladder cancer. He spends much time in the hospital, for the physicians hope to cure him. Unfortunately, every procedure causes further trouble. In the end the family unanimously decides to write no code in the chart so that nothing further will be done. In both memoirs the pain of loss is increased by the sense of helplessness. Still, L'Engle realizes how lucky she is. She is surrounded by loving friends who give support during and after the ordeal, and the church offers her companionship and solace.

A. G. Mojtabai's (b. 1937) *Autumn* (1982) and her short stories in the collection *Soon* (1998) describe people caught in liminal states between life and death. These threshold moments are bewildering and not always subject to human will. *Autumn*, published when Mojtabai was 45, is a sensitive study of Will Ross, a man of 66, in mourning for his wife. He thinks he has things under control, but he does not. Troubled by the unresolved conflicts in his life, he believes that his tree house contains a comatose young man. At one point he recalls sleepwalking through his own youth. At the novel's end the boy disappears, and Will thinks he hears someone calling him. He answers, but the novel ends shrouded in ambiguity.

Autumn's ending has much in common with Mojtabai's short stories in *Soon: Tales from Hospice*, published 16 years later. They are based on the novelist's work as a volunteer in a hospice, where she longed to fill in the missing details of the patients' lives. Unable to ask them pertinent questions, she invented her own answers. The stories depict patients and families who are awaiting the moment that they or their relative will die. The stories employ different perspectives, sometimes that of the patient, the family, or members of the staff. Death is taken seriously, as are questions of religious belief and skepticism.

English novelist Graham Swift's (b. 1949) *Last Orders* (1996), winner of the Booker Prize, describes the effect of one man's death on his four friends and their families. Written when Swift was in his mid 40s, the novel interweaves events from the past and the present. The four friends and Jack Dodds' adopted son take turns describing their journey to Margate, where they must scatter Dodd's ashes. The trip is arduous because each person has unfinished business with Jack and the other survivors.

Swan Songs

In this context, swan songs are narratives written when their authors knew that their time on earth would soon end. For three novelists, Barbara Pym, Carol Shields, and Paul Scott, writing was a lifeline that none of them wished to abandon. Death, however, is not necessarily a topic that they chose to pursue in their final novels. Instead, Pym and Shields wrote obliquely about life's end, whereas Scott approached the subject more directly.

Barbara Pym began *A Few Green Leaves* in 1978 at age 65, before she learned that she had a new malignancy that would shorten her life. Still, when she wrote the final draft, she did not make it lugubrious. Instead, she maintained such an objective stance that the casual reader would not guess that the author was facing her own death. Although images of death permeate the novel, death is not always treated with great seriousness. On one occasion, her youngish heroine, Emma, makes fun of the subject, unable to imagine her own demise. When Miss Lickerish, an elderly village eccentric, dies, Pym describes the church service in considerable detail, taking pleasure as if she were stage managing her own funeral. Ritual was comforting to Pym even in extremis.

American-born Canadian novelist Carol Shields (1935–2003) published *Unless* (2002) after she had been told she had stage four breast cancer, for which no cure exists. The 44-year-old main character, Reta Winters, suddenly has her life shattered when her eldest daughter drops out of university. She sits in the street holding a sign saying Goodness, begging from those who emerge from a subway stop in Toronto. Although Reta clings to her writing life, the loss of her daughter makes her feel as if her heart is breaking. Not surprisingly, the novel has melancholy overtones, and at times the novelist expresses anger at the treatment of women and women novelists in particular.

English novelist Paul Scott (1920–78) wrote *Staying On* (1977) while he was gravely ill. Scott was working on another novel when *Staying On* won the Booker Prize. Many regard the novel as the coda of *The Raj Quartet* (1966–75), his four-volume epic of the last days of English rule in India. In it, two minor characters from the early novels, Lucy and Tusker Smalley, become the chief protagonists. They have stayed in India after partition, but their situation becomes more tenuous even before Tusker dies. Mrs. Bhoolabhoy, who owns their dwelling, an old hotel, the only place the Smalleys can afford, is determined to sell it. Like the other swan songs, this one leavens the grimness of death and loss with humor and with rich descriptions of life in India. Lucy and Tusker may be losers, but Scott portrays them with great sympathy and affection. The novel begins and ends with Tusker's death, but only at the end does one know how desperate Lucy's life will be. She tries to be brave but ends by calling out to her dead husband, asking how can he desert her in an alien land.

Conclusion

In conclusion, aging has become such an important topic in modern life that even some comic strips feature older characters. Not only do grandparents play supporting roles in mainstream comics, such as Lynn Johnston's (b. 1947) "For Better or For Worse," but they also dominate strips such as Aaron McGruder's (b. 1974) "The Boondocks" and Brian Crane's (b. 1949) "Pickles." The grandfather in "The Boondocks" shares the stage with his young grandsons and their friends. Their disparate perspectives provide intergenerational humor and conflict. In contrast, "Pickles" is devoted to the daily life of an elderly couple. In it, their daughter and grandson appear as minor figures. Unlike American movies and television, which desperately seek a young audience, comics, like fiction, can appeal to people of all ages. In the future, as populations age, we will see even more literary works devoted to aging characters and themes, written from a variety of perspectives.

See also: Bereavement and Loss; Death and Dying; Grandparenthood; Images of Aging; Life Review; Mid-Life and Later-Life Crises; Retirement.

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Loneliness

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Glossary

Emotional Isolation – The lack of person(s) to whom one feels attached (i.e., emotionally committed).

Loneliness – A psychosocial emotional condition that may stem from many factors, but that is usually related to either social isolation or emotional isolation.

Social Isolation – The lack of, or a deficit in, the quantity of a social network.

Introduction

This article first looks at loneliness from a social problems perspective and examines whether loneliness in old age is a myth. Next, the focus shifts to a general examination of the two broad conceptual and theoretical approaches that have driven the examination of loneliness. One perspective focuses on a micro-social, or social psychological, framework, while another perspective emphasizes a sociological and cultural orientation. Also, the primary trends in

loneliness research with special emphasis on social relationships and health are examined. Further, there is a discussion of the two primary measures of loneliness. Finally, an overview of intervention strategies that can be used to reduce loneliness is presented.

Loneliness, especially in old age, is a condition and a concept that on the surface appears to be understandable to everyone. We have all heard such statements as 'her husband died last year; she is lonely,' or 'he has been living alone for six years; he must be lonely.' The reality is that loneliness is a theoretically and conceptually complex idea, which in its social, psychological, and behavioral effects can be emotionally and perhaps physically debilitating.

Loneliness as a Social Problem

One such issue concerns whether loneliness is viewed as a social problem, i.e., the focus is on the magnitude of the problem. In 1986, Revenson argued that loneliness in old age is simply a myth that should not be continued. The 1974 NCOA (National Council on the Aging) Survey showed that among those under age 65, 61% viewed loneliness as a very serious concern for those over 65. In 1981, the comparable figure was 65%. In 2000, the same type of evaluation indicated that 38% of those under 65 saw loneliness as a very serious concern for those over 65. The general American public under age 65 certainly does not view loneliness in old age as a myth, though the perception of it as a problem is declining.

What about the elderly themselves? Among those age 65 and under, 38% in 1974 and 21% in 2000 viewed loneliness as a very serious or somewhat serious problem. It could be concluded that loneliness is still a problem among older persons, but the extent of the problem is decreasing. Still, 21% of those 65 and over represents more than a fifth of the 35 million older persons in the United States in 2000, i.e., more than 7.3 million older persons.

Whether such figures indicate that loneliness is or is not a social problem is a conclusion for others to draw. The figures presented here, however, do lend credence to the focus that has been placed on the examination of the causes and effects of loneliness among the elderly over the past 30 years.

The growth in the number of older persons worldwide, especially in developed countries, has stimulated much interest in their various needs and conditions. Loneliness is one of those conditions that has generated considerable examination. Much of the focus in loneliness research has come from a micro-level of analysis. Researchers have typically focused on variables at the individual level, especially looking at issues of individual health characteristics, gender, age, and, most particularly, the quantity and/or quality of contact and relationships with friends and/or family.

Micro-Social Perspective of Loneliness

The theoretical foundation of loneliness research from a micro-social perspective began in the 1950s and 1960s. The best review of this foundation comes from Marangoni and Ickes. They point out that the theoretical approaches can be broadly classified as one of several categories: (1) the behavioral approach, represented by the behavioral problems and social skills deficits perspective; (2) the personality explanations; (3) the cognitive processes approach; (4) the social needs approach–neo-Freudian; and (5) the social support perspective. An examination of these approaches leads to an identification of several common themes: (1) loneliness is a subjectively experienced emotional condition with no necessary association with social isolation; (2) loneliness is an aversive psychological condition; and (3) the underlying cause of loneliness results in some way from deficits in social relationships. The various theoretical orientations essentially differ in how and why social deficits lead to the experience of loneliness.

The importance of a phenomenological, *qua* existential, approach is clearly seen in the classic distinction made between feeling lonely and being alone. A person may live alone and have relatively few social contacts, but still seldom feel lonely. Conversely, persons may have chronic feelings of loneliness even when in a crowd or surrounded by others. The objective fact of social isolation and the subjective experience of emotional isolation are by no means equivalent.

It is important also to distinguish among different types of subjective loneliness. Young identified three distinct types: chronic loneliness, transient loneliness, and situational loneliness. Chronic loneliness concerns persistent deficiencies that people experience in their social relationships for at least two or more consecutive years. Transient loneliness refers to occasional feelings of loneliness, such as those that many people experience from time to time, that are not persistent for more than brief periods of time. Situational loneliness results when individuals are confronted with a specific crisis or loss, such as the death of a spouse.

The lines between these types of loneliness are not absolute. For example, a person may experience situational loneliness as a result of a particular loss from which recovery does not occur; thus, situational loneliness gradually transforms into chronic loneliness. Or episodes of transient loneliness may become

more frequent, ultimately resulting in chronic loneliness. The reasons for such increases in loneliness could be traced to social or psychological changes that are associated with the process of growing old.

Under normal circumstances, there are gradual changes, such as the gradual reduction of social contacts, that can trigger the transformation of transient or situational loneliness to chronic loneliness. Among the chronically lonely, however, there may be brief interludes when the acute pain of loneliness is lifted temporarily, e.g., when there is an overwhelming but temporary increase in social contacts at a family reunion.

Macro-Social Perspective of Loneliness

While much of the attention, both theoretically and empirically, has been given to the micro-level of examination, more emphasis needs to be placed on the macro-level, i.e., the examination of sociological and cultural variables in their impact on explaining both isolation and emotional loneliness.

Additionally, cross-cultural comparative work would be invaluable in furthering understanding. Cross-cultural comparative analysis is needed to sort out what is culturally specific and social psychologically general. A comparative perspective is not necessarily limited to the general cultural or subcultural environment, however. It can also deal with the relationship between subjective feelings of loneliness and the social networks in which older persons are involved. These networks, also, can be affected by the type of living arrangements in which older persons are involved, their health, their socioeconomic status, their family structure, and various other indicators of opportunities for social contact.

The basic approach underlying this type of examination can be summarized as follows. (1) People with differences in basic personality structures vary in terms of their social needs, especially needs for sustained or intense intimate interaction with others. (2) Individuals' basic personality structures are formed in large part by the type of basic cultural value system that they have internalized. (3) Because societies differ in terms of their basic cultural value orientations, personality patterns, especially needs for social interaction, will likewise vary in different societies. (4) The crucial importance of cultural variations for personality formation also applies to subcultural variations within a complex and pluralistic society.

While these basic principles focus primarily on the subjective level, objective variables may readily be incorporated into the model. The importance of such variables and their relationship to the subjective level can be expressed as follows. (1) Societies differ in terms of the opportunities provided to older persons to develop or maintain a desired level of social contacts. (2) Similarly, within a complex or pluralistic society, different segments of society vary in the same way. These variations in objective opportunities for social contact are no doubt influenced by numerous other social structural variables, including, for example, the preferred social role for older persons, density of communities in which older persons live, specific living arrangements, marital status, health and mobility skills, socioeconomic status, and so forth.

However, in order for us to understand the problem of loneliness among older persons, these variations in objective opportunities for social contacts must be related to individuals' subjective needs and desires. Accordingly, the following basic principle is pertinent: for any particular level of opportunity for social contacts, a person's evaluation of its adequacy or deficiency is based on a subjective comparison (not necessarily conscious) of that level with the level of social interaction that is expected, needed, or desired within the culture. Expectations, needs, and desires, in turn, result in large part from basic personality structure. Because of the difference among people in this regard, the concept of the 'loneliness threshold' is a potentially crucial consideration. The loneliness threshold is the minimal level of social contact that is needed for a person to avoid the subjective experience of loneliness. Although individually specific, it is heavily influenced by the basic cultural or subcultural value systems that the individual has internalized.

Trends in Research

Loneliness and Social Relationships

A key question in loneliness research, to paraphrase Dykstra, is 'What is it about social relationships that influences loneliness?' When the impact on loneliness of different forms of relationships is examined, the conclusions reached are quite varied. For example, research on the spousal relationship has often focused on examining loneliness among persons who were married, but are now widowed. Widowhood, i.e., the loss of a significant other, is shown to be a major risk factor in the manifestation of loneliness among older persons. This perspective assumes the loss of both a social and emotional companionship. More research, however, needs to focus on the development of loneliness while the marital relationship still exists. That is, among married older persons, how does the level of emotional commitment

between the partners influence the loneliness experienced?

Adult children, of course, are important to the well-being of older persons, e.g., providing financial assistance, emergency assistance, and help with health care. Those older persons without children are more likely to live alone and, if alone, are less likely to have had recent social contact. Research does not show, however, that childless older persons are any more lonely than those with children.

An area neglected by loneliness research is the contact and emotional relationship older persons have with grandchildren and with siblings. Grandchildren provide a potential source of emotional intimacy that has not been fully examined. The facts that three-quarters of all older persons in the United Stated have living grandchildren and that half have contact with grandchildren every day or so indicate an emotional and social context important to well-being.

The impact of sibling relationships on loneliness has also been a neglected area of study. Cicirelli observed that the sibling relationship can be of the longest duration and may be the most egalitarian of kin relationships. The limited research findings, however, are mixed. There are indications that sibling relationships can either reduce loneliness or not influence loneliness.

The greatest emphasis in loneliness research has been on the friendship relationship. Hochschild indicated that friendships foster a kind of belonging based on proximity and conviviality. Unlike family ties, which remain consistent through old age, contact with friends can be more varied. Friendships are not formally prescribed, as are kinship roles, and require both initiative and sustenance by both parties to be successful. Although some conditions associated with aging may change, e.g., health or economic conditions and geographic distance, many older adults maintain some friendships for many decades.

Research has shown that friends, especially close friends, exert a positive influence on the emotional well-being of older persons. Friends provide numerous forms of social and emotional support that are valued and appreciated especially because the support is non-obligatory. Friends clearly are important in preventing or reducing loneliness. Generally, older persons who have sufficient contact with friends, especially those residing near them, and who are satisfied with those relationships, experience less loneliness.

The Impact of Health and Selected Other Characteristics on Loneliness

Though there are both objective and subjective components to health consideration, previous research has not systematically made a distinction of the influence such variables would have on the experience of loneliness. The health of older persons consistently has been shown to be related to their emotional well-being. Considerable consistency in loneliness research indicates a strong association between poor health, especially subjectively assessed poor health, and loneliness. A lingering issue, though, is whether greater loneliness leads to poor health, or whether poor health leads to greater loneliness.

There are a number of other characteristics that need to be further examined with respect to loneliness. Some of the more obvious are age, gender, race and ethnicity, rural and urban settings, education and income, place of residency within the continuum of care, and religious background and religiosity. Each of these has been examined with respect to loneliness, either specifically or as a control variable in studies focusing on other issues; a brief overview of this research follows.

Studies do not show a clearly identified gender-specific effect on loneliness. However, the research suggests that either gender is not important, or women are more lonely and men are more isolated. The examination of differences by race and/or ethnicity does not show any particular difference in loneliness. There is some evidence that those living in rural areas are more likely to experience loneliness, due to factors associated with social isolation. There is no particular conclusive finding that education or income is related to loneliness. The adequacy of income, a subjective measure, does show some relationship to loneliness.

There is a general indication that loneliness increases for persons residing in increasingly restrictive levels of care. Research in the Netherlands, however, shows a decline in loneliness upon admission to a residential facility. Also, while there has been no work comparing loneliness experiences with respect to religious denominations or tenets of faith, there is evidence that the associational or communal aspect of church attendance is related to loneliness, while the subjective element of religious commitment is not.

Measurement of Loneliness

While there are a number of scales that measure feelings of loneliness, there are two that have received the most use and attention. Both measures are based on a cognitive approach to loneliness. The UCLA Loneliness Scale, originally developed by Russell, Peplau, and Cutrona, has been utilized in several forms, i.e., a long and a short form. The 'revised' scale, consisting of 20 items and published in 1980,

examined concurrent and discriminate validity. The scale consists of 10 positively and 10 negatively scored items. An example of a positively scored item is 'I feel isolated from others.' The scale has shown consistently high internal consistency, with a coefficient alpha of greater than 0.90. An example of a negatively scored item is 'I do not feel alone.' The scoring is based on a four-point scale with higher scores indicating a greater expression of loneliness.

Another measure that has been used extensively is the Loneliness Scale developed in the Netherlands by DeJong-Gierveld and associates. Originally a 34-item multidimensional scale, the final scale consists of 11 items. It can be used in face-to-face interviews or as a self-administered test. It also consists of positively (five items) and negatively (six items) specified items. A positive item is, for example, 'There is always someone I can talk to about my day-to-day problems.' An example of a negative item is 'I experience a general sense of emptiness.' Scale scores, ranging from 0 to 11, are based on summing dichotomous item scores. The total loneliness score can be categorized as one of four levels: not lonely (0–2), moderate loneliness (3–8), severe loneliness (9–10), and very severe loneliness (11). This scale also has reasonably high internal consistency – alpha coefficients in various studies range from 0.80 to over 0.90.

A caveat about these scales concerns the positive and negative nature of the items. An examination of the factor or content structure of these scales usually shows two dimensions. One dimension consists of the positive items, which assess feelings of belonging, while the other dimension consists of the negative items, which seem to relate to missing relationships.

Of course, whether the UCLA Scale, the DeJong-Gierveld Scale, or another is used is at the researcher's discretion. The essential issue of which is best is based on the needs of the research conducted.

Intervention Strategies for Loneliness

Intervention strategies for the amelioration of loneliness can take many forms. Broadly conceived, these approaches can take three forms: those that are individually oriented, those that are group oriented, and those that are environmentally focused.

Individual Approaches

The interventions targeting individuals include interpersonal therapies, psychodynamic therapies, cognitive-behavioral therapy, and friendly visitor programs.

Interpersonal Therapies In a Rogerian and humanistic framework, interpersonal therapies consider loneliness as a result of the person's belief that without conformity to social norms social rejection will result. In effect, the self is unlovable. The therapeutic approach is to develop a client–therapist rapport, which, through free interchange, will reduce the individual's fear of rejection and provide a new experience with interpersonal relationships.

Psychodynamic Therapies Similar to the interpersonal strategies, the psychodynamic approaches look at the lonely client–therapist relationship. Through the transference between the lonely individual and the therapist, the childhood conflicts and difficulties that have made adult social bonding ineffectual are identified. Such issues as dependency, hostility, and intimacy are examined with regard to their impact on the manifestation of loneliness.

Cognitive-Behavior Therapies This approach suggests that negative cognitive presumptions regarding interpersonal relationships can lead to emotional isolation. For example, it has been found in several studies since the mid-1970s that those who experience greater cynicism, mistrust, and negativity of peer ratings and who are vigilant and hyperalert to threats in social encounters tend to experience loneliness. The therapeutic rationale is focused on influencing the lonely person's perception of interpersonal relationships. In effect, the person is trained to recognize and change what are presumed to be inaccurate perceptions of social interchange.

Friendly Visitor Programs Probably the most straightforward therapeutic approach is the provision of friendly visitors. In this approach, programs typically are aimed at persons who are considered to be socially and physically isolated. While such programs do have at least short-term effects, they are usually broadly sweeping with little attempt at targeting the particular social relationship most in need of change, or in ameliorating other considerations, e.g., health and economic condition.

Group Approaches

Similar to the individual approaches to the resolution of loneliness are the group approaches. In group approaches, the focus is on specific target groups. Professional interventions using a cognitive approach in combination with group process techniques have been useful in maintaining self-esteem and in facilitating emotional adjustment. Most interventions within this context emphasize the development of skills needed to initiate social contact, e.g., social

skills training for the socially isolated, those who are shy, or those who have inhibitions of social risk taking. Particularly effective within the group context is the ability to capitalize on the often-noted association between depression and loneliness. Group therapy procedures that prove effective in alleviating depression would likely reduce the distress associated with loneliness.

Environmental Approaches

The two preceding approaches to loneliness reduction attempt to educate or change the person in some way in order to increase the satisfaction the person experiences with social ties. The alternative approach is to design the environment in such a way as to facilitate social interaction and (either intentional or unintentional) network building. Enhancing, as Hochschild described, the 'web of sociability' is viewed as a positive approach to cooperative task development.

Senior centers, congregate programs, home-delivered meal programs, adult day care programs, and transportation programs would be well-served by looking into creative ways to design their programs in order to facilitate social integration and emotional attachment, opportunities to give and receive support, and enhance feelings of personal worth.

In sum, there are many varied approaches that may be useful for the alleviation and/or prevention of loneliness. Much work needs to be done that systematically addresses the emotional condition of older persons within the context of not only their interpersonal relationships, but also the sociodemographic situations and health conditions within which they find themselves. Treatment and therapeutic regimens must be developed that are understandable, developed for specific groups based on needs, and testable.

See also: Demography; Depression; Emotions; Psychological Well-Being; Social Networks, Support, and Integration; Widowhood and Widowerhood.

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Long Term Care

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Glossary

Culture Change – A transformation in long-term care that is bringing control to older adults and those who work closest with them, such that care is becoming more person-directed and focused on relationships, rather than on the task of care provision.

Dementia – A progressive, irreversible, organic brain disease that involves a reduction in memory and multiple other categories of cognitive ability, with the impairment being sufficient to interfere with self-maintenance, work, and/or social relationships.

Nursing Homes – Facilities with three or more beds that provide 24-hour nursing care services. More narrow definitions require the facility to be certified by Medicare or Medicaid.

Quality of Care – The structure and process of care that result in outcomes, with the understanding that quality care increases the likelihood of desired outcomes.

Quality of Life – The essential conditions beyond survival that are needed for individuals to have experiences that provide meaning and joy to their time.

Residential Care/Assisted Living – Facilities that are not licensed as a nursing home; house two or more unrelated adults; provide room, board, 24-hour oversight, and personal care; and can respond to unscheduled needs for assistance. More narrow definitions consider assisted living to be those residences that have apartments rather than rooms and/or that embrace a distinct philosophy of care.

Introduction

Long-term care is the broad range of personal, social, and medical services that assist people who have functional or cognitive limitations in their ability to perform self-care and other activities. With the growth of our older population, long-term care has become a major component of the United States health-care system. These services are provided in a multitude of locations, including private homes, adult day-care settings, residential care/assisted living facilities, and nursing homes. This article focuses on those last two settings, both of which constitute residential long-term care. In 2005, there were approximately 17 000 nursing homes in the United States, with 1.9 million beds, serving 1.6 million persons. Almost one-half of the nation's population aged 65 and older will spend at least some time in a nursing home, and in many states, nursing home care consumes over 50% of the Medicaid budget. Furthermore, nursing homes are only a portion of the residential long-term care system; nationwide, residential care/assisted living facilities have proliferated since the 1990s, to the point that the number of beds in these residences rivals that in nursing homes. In 2005 there were approximately 36 000 residential care/assisted living facilities in the United States, housing as many as 1 million older adults.

Nursing Homes

Overview

Since the inception of Medicare, nursing homes (also referred to as skilled nursing facilities) have been the predominant form of residential long-term care in the United States. They provide 24-hour nursing care, supervision, help with activities of daily living, meals, and medication administration to people who cannot manage independently. They also provide rehabilitative services, including physical, occupational, and speech therapy, to assist those recovering from acute conditions such as stroke or hip fracture. The vast majority of nursing home residents are elderly, and in general, nursing homes have consistently housed approximately 5% of the US population age 65 and older.

The predominant model of nursing home care is medical, ordered by physicians, planned primarily by licensed nurses, and delivered by certified nursing assistants and other professional or paraprofessional staff. Because nursing homes are tightly controlled by federal regulations, much of the administrative structure, staffing, and physical characteristics of one facility are similar to those of any others. However, as discussed later in this article, the field of long-term care is embracing a culture change movement, which may allow for more diversity, and improved quality of care, in these settings.

Clientele

Reflecting the demographics of the population, the majority (almost 75%) of nursing home residents are women. The average age at admission is 84, and

approximately one-half of residents are 85 years of age and older. Overall, an estimated 75% of nursing home residents require assistance in three or more activities of daily living, such as bathing, dressing, eating, transferring from a bed to a chair, and using the toilet. Approximately one-third of admissions are for short-term rehabilitation after hospitalization (e.g., for a stroke or hip fracture), although those receiving rehabilitation occupy less than 10% of nursing home beds. One-half of new admissions have dementia (this condition being one of the primary reasons for admission), with 'long-stay' residents displaying a higher dementia prevalence – up to 75% – as well as disabling chronic medical conditions. Reflecting the long-term care needs of the population, of all those in a nursing home at any one time, fewer than 20% have been there for less than 3 months. Overall, the average length of time since admission among all residents currently living in a nursing home is 2.5 years.

Regulation

Most federal regulations of nursing home care are linked to federal funding of services through Medicare and Medicaid programs. The primary elements of regulation consist of establishing standards for providers, assessing compliance, and imposing sanctions for non-compliance. The Nursing Home Reform Act of 1987 created the most far-reaching changes in nursing home regulation since Medicare and Medicaid were created in 1965. It focuses on numerous components of care, including resident rights, quality of life, and quality of care; staffing and services; resident assessment; federal survey procedures; and enforcement procedures. The survey (and certification) process is conducted annually under contract by state agencies, and uses observation, record review, and interviews with residents, family members, and facility staff. Facilities that do not meet standards are given a deficiency of varying levels, depending on the severity of the infraction. Enforcement of regulations has resulted in a decline in the number of deficiencies, but weaknesses in the system remain, including variation across states and concerns that the survey process does not always detect serious quality of care problems such as falls, restraint use, infection, and even death.

Funding

The average annual cost of nursing home care is about $56 000, or $153 per day, with total national expenditures reaching $78.6 billion (1998 dollars). For those receiving rehabilitation after a hospital stay, Medicare covers 100 days of skilled care per benefit period. Given that the majority of residents are not receiving nursing home care under this condition, it should come as no surprise that Medicare supports only a limited amount of nursing home costs (13%; the equivalent of $10.4 billion in 1998). Medicaid funds 40% of nursing home costs ($31.4 billion) followed closely by private, out-of-pocket payments (36%, $28.5 billion).

Table 1 overviews some of the components of nursing homes, allowing for a comparison with residential care/assisted living facilities.

Table 1 Comparison of nursing homes and residential care/assisted living facilities

	Nursing homes	*Residential care/assisted living*
Number of facilities in the United States	17 000	36 000
Number of beds in the United States	1.8 million	1.0 million
Average size	120 beds	9–65 beds (depending on type)
Predominant model of care	Medical	Social
Involvement of licensed nurses	24 hours/day	Variable, often as supervisors rather than direct care providers
Physician visits	Typically occur in the facility; required every 60 days	Typically occur in the physician's office; required once a year
Nursing procedures, physical therapy	Provided by facility staff	Provided by facility staff, home health personnel or not at all
Help with activities of daily living, e.g., dressing, grooming, eating	Provided by facility staff	Provided by facility staff
Payment sources (approximate)	Private pay, 44% Medicaid, 40% Medicare, 13% Other public funds, 2%	Private pay (including Social Security Disability), 85% Medicaid and other public funds, 15%
Percent of facilities with majority of beds in private rooms	11	55–75 (depending on type)

Residential Care/Assisted Living

Overview

While nursing homes have been the primary source of institutional care for older adults since the inception of Medicare and Medicaid, the combined impact of increasing numbers and the overall better health of new cohorts of older adults, a shortage of nursing home beds, rising costs of care, and dissatisfaction with nursing home care made evident a gap in the continuum of care between independent housing that caters to those without any impairments and nursing homes that caters to the chronically ill. As early as the 1940s, board and care was the model of housing and services that fit into this gap. In recent years, however, residential care/assisted living became the fastest-growing segment of the senior housing market, such that a variety of residences now exist. Despite wide variations, these residences have in common the fact that they all provide room, board, 24-hour supervision, and assistance with medications and activities of daily living. Facilities also tend to provide some degree of coordination of and access to medical and nursing services, although the extent of services varies widely.

In a purist sense, the term assisted living initially referred to a specific model of care based on principles of individuality, independence, privacy, dignity, and choice; it embraced homelikeness, with individual sleeping spaces, full baths, kitchens, doors that locked, individual temperature controls, and personal furnishings; and it introduced concepts such as customized care plans and managed risk contracts. By the mid-1990s, however, it became evident that the term assisted living was being used broadly to refer to a diversity of facilities regulated by the states under a variety of designations, including board and care, residential care, personal care, foster care, domiciliary care, and congregate care – and not all of which subscribed to these principles. Because of this broadened use of the term assisted living, it is more clear to refer to all such settings as residential care/assisted living facilities.

Residential care/assisted living facilities range from private, converted houses with fewer than 10 beds to multilevel campuses with more than 1400 beds. Some have private apartments, whereas others have four residents per room. Rates range from less than $400 to more than $6000 per month. Given this diversity, typologies to create an organizing framework for residential care/assisted living have been suggested. Some typologies address differences in structure and access (public housing, units in continuing care retirement communities, freestanding facilities), differences in services (institutional board and care, housing and services, purely service-oriented), differences in the combination of services and privacy (low/minimal privacy and service, high privacy and low service, high service and low privacy, high privacy and high service), and differences across a combination of size and medical needs/services (residential care/assisted living facilities with fewer than 16 beds, traditional facilities, and new-model facilities that provide medical services to an impaired population). To illustrate the differences across facility types, some components of facilities categorized using this latter typology are shown in **Table 2**.

Clientele

Over time, residents in residential care/assisted living facilities have come to resemble nursing home residents of the 1980s. Like the residents of nursing homes, the majority (75%) are female. Depending on the type of residential care/assisted living residence, as many as 40% of residents are impaired in performing activities of daily living, have moderate or severe dementia, or display behavioral symptoms. The exact composition of the resident profile is somewhat dependent on state regulations, however, as admission and retention criteria define the client population and the limits to which residents are allowed to age-in-place. Across the states, state regulatory restrictions range from none (as is the case in Alaska, for example) to very specific exclusionary criteria such as the number of activities of daily living with which a resident can need assistance (as is the case in Illinois). The intent of these regulations is to restrict resident need to the services that a residence is able to provide or secure – although in some states (including New Jersey), acceptable levels of need may be as high as those necessitating 24-hour nursing care. In addition, variability is allowed within states, if a residence can meet additional regulations to care for more impaired residents.

Regulation

The regulatory environment in residential care/assisted living is dynamic; regulations will continue to evolve as this field emerges as an alternative to other forms of long-term care. Unlike nursing homes, however, there is no overarching federal regulatory body for residential care/assisted living; instead, individual states are empowered to define, license, regulate, fund, and oversee it. Between the years 2000 and 2002, virtually every state addressed issues of residential care/assisted living regulation, doing so with regulatory models ranging from those that are highly defined and prescriptive with detailed criteria

Table 2 One typology of residential care/assisted living

	Type		
	< 16 beds	*Traditional*	*New-model*
Facilities			
Distinguishing characteristics	< 16 beds; often in converted private homes in residential neighborhoods	> 16 beds; older; fewer medical services	> 16 beds; newer; more medical services
Common licensure names (vary according to state)	Adult foster care Family care Senior group homes Sheltered housing Assisted living	Board and care Congregate living Domiciliary care Residential care Assisted living	Assisted living Homes for the aged Residential care
Average number of beds	9	46	65
Mean facility age (years)	13	23	5
Average number of employees	5	21	33
Percent for-profit	91	65	73
Residents			
Mean age of residents	83	85	85
Percent of residents with:			
Dementia	40	21	34
Impairment in ≥ two activities of daily living	56	34	46
Percent of non-white residents	9	4	3

to those that are broad and general, using criteria as non-specific as 'meeting resident needs.' To further complicate the issue, approximately one-third of states do not even use the term assisted living in their licensing regulations. Further, only slightly more than one-half of the states describe their philosophy of care as part of their regulations.

Funding

The average cost of residential care/assisted living is approximately $30 000 a year. To date, residential care/assisted living facilities has been mostly private pay; however, with the growth of the industry and increased provision of services to impaired older adults, there has been a trend toward public subsidies. By 2003, 41 states provided funding for residential care/assisted living services. Methods of payment are diverse, however, with states providing payment as a flat rate (32%), tiered rate (27%), in accordance with care plans (24%), or resident case mix (<1%). Twelve states allow room and board to be covered, but this constitutes an ongoing controversy. That is, because assisted living is considered to be a residential setting providing services based on a social model rather than medical model of care, the implication is that room and board is a primary service; however, room and board traditionally have been (and continue to be) excluded from Medicaid coverage. Thus, despite some public support, private sources (i.e., resident and family funds) continue to provide the majority of payments (75%), with trivial additional amounts from long-term care insurance (<2%) and managed care (<2%). The remaining costs are covered through a combination of Medicaid waivers, state funds, and Supplemental Security Income (SSI).

Current Issues in Long-Term Care

Nursing homes and residential care/assisted living facilities are complex settings that provide for the care of frail, chronically ill persons. Not surprisingly, numerous issues exist regarding the optimal provision of care in these settings and the extent to which it is in need of improvement. Those issues that are reviewed here are the relative roles of nursing homes and residential care/assisted living, dementia care, quality of life, access to and disparities in care, rehabilitation services, medical management, physician services, end-of-life care, family involvement, staffing, abuse and neglect, the quality of care, and culture change in long-term care.

The Relative Roles of Nursing Homes and Residential Care/Assisted Living

The variability of residential care/assisted living has resulted in two differing perspectives on its role in the system of long-term care: one is that it lies along a continuum between home care and nursing home care, and the other is that it constitutes an approach and philosophy that can apply to all persons, regardless of their level-of-care needs. Consequently, there

has been some dynamic tension between the residential care/assisted living and nursing home industries, with the former being viewed as competing with nursing homes for many of the same individuals. Furthermore, although reliable data are not plentiful, there is evidence that residential care/assisted living facilities may be able to serve some (but not all) individuals as well as and at a lower cost than nursing homes. Overall, the matter seems to be resolving itself such that nursing homes are caring for an increasingly rehabilitative and frail population, while residential care/assisted living caters to those with functional and cognitive limitations.

Dementia Care

Even as residential care/assisted living takes care of an increasing number of persons with dementia, the prevalence of this condition is such that significant numbers of nursing home residents will continue to be impaired as well. In the 1990s, almost one-quarter of nursing homes responded to this need by developing and marketing special dementia care in the form of units dedicated to the care of persons with dementia. These units were thought to be a superior treatment environment for persons with dementia because they were purported to specially select, train, and supervise their staff; provide activities specially designed for the cognitively impaired; involve the family in treatment; and have a physical environment designed for safety and segregation. However, much as the philosophy of assisted living is not always practiced, these components of special care were not always evidenced. In addition, the provision of special care did not consistently relate to better care, in terms of resident outcomes (e.g., cognition, function, behavior, mood, discomfort, hospitalization), staff outcomes (e.g., stress, burnout), and family outcomes (e.g., depression, satisfaction). Specialized dementia care is growing in residential care/assisted living, but of the total number of people with dementia in long-term care, the vast majority are not treated in special units. Thus, dementia care has become the province of all long-term care providers.

Quality of Life

One of the most important changes that has begun and will continue to impact the future of long-term care is the understanding that those who live there are not merely waiting to die. Instead, despite their need for care and support, they remain able to experience joy, accomplishment, meaningful relationships, a sense of comfort, and other pleasures that jointly are referred to as quality of life. Thus, as the focus of long-term care evaluation and research has gradually shifted from how care is delivered (process of care) to how care affects residents (outcomes of care), accompanying this shift has been the recognition that the primary outcome of interest should be the quality of life achieved by its residents. Even nursing homes are being recognized as providing more than medical and nursing care, and all long-term care settings are being called upon to attend to the conditions that are necessary for individuals to have experiences that provide meaning and joy to their time. One manner in which this philosophy is being operationalized relates to resident autonomy, self-governance, and the right to make decisions about care and to take responsibility for risks that may result from those decisions. This concept of negotiated risk suggests that even while individuals are residents of group settings, they have the right to live a life of their choosing.

Access to and Disparities in Care

The current trend is for long-term care in the United States to be increasingly segregated by payment status, with nursing homes primarily serving a Medicaid clientele and residential care/assisted living facilities serving those who can pay privately. Early board-and-care type residential care/assisted living served low-income older adults who could not live independently and relied on Medicaid, SSI, or other state and federal government funds. As the field grew and the business community recognized residential care/assisted living as a profit-making opportunity, a schism developed between modest facilities catering to residents of lesser means and more upscale facilities serving residents able to afford substantial private pay rates. Consequently, the industry is now largely private pay-based and unaffordable for low- or moderate-income persons. Due to this economic and other social factors, the proportion of residents who are minorities is minimal. Indeed, between one-half and three-quarters of residential care/assisted living facilities have no African American residents. This distinction contrasts with northern European models of long-term care, which have emphasized serving the broad range of the community through the generous use of public revenues. Such a solution appears unlikely in the United States, but a variety of states are experimenting with creative models of financing to provide affordable assisted living. Offering residential care/assisted living to persons who cannot afford to pay is an important policy issue, and not doing so further compounds the disparity in nursing home care that currently exists and is reflected in the proportion of those receiving Medicaid.

Rehabilitation Services

Persons who have been hospitalized for an acute medical or surgical problem often need a period of therapy and recuperation before they can return to their homes in the community. A few who meet very strict criteria are admitted to special rehabilitation hospitals, but the majority of these individuals (including most of the elderly) are cared for in nursing homes. Rehabilitation is the only instance of long-term care provision for which Medicare and most private insurance plans will pay for room, board, and treatment; in the case of Medicare, a rehabilitable condition (e.g., stroke or hip fracture) and a 3-day hospital stay are required to receive reimbursement. Nursing home rehabilitation personnel include physical therapists, occupational therapists, and speech therapists, who work with physicians to plan and implement treatment aimed at improving and maximizing function. Barriers to successful rehabilitation at home include severe cognitive impairment (causing problems learning or re-learning needed skills), severe medical impairment (such as dyspnea at rest or a stroke with complete paralysis on one side), and an unsuitable discharge residence (one that lacks necessary supports). In such situations, the long-term care facility may become the individual's permanent home.

Medical Management

A variety of medical problems are quite common among residents of nursing homes and residential care/assisted living residences. Dementia and less severe cognitive impairment are present in the vast majority. Other conditions include arthritis and osteoporosis (often with a history of compression fractures of the spine), leading to a high prevalence of chronic pain, especially upon movement. Hearing loss and visual impairment are also common, with as many as one-third of long-term care residents having severe impairment in one or both of these senses. Other common medical conditions in this population include congestive heart failure, diabetes, chronic lung disease, hypertension, and urinary incontinence. Thus, it is not surprising that the average long-term care resident takes between five and ten medications and that monitoring health status and medications is a major issue for facility staff. A particularly common and challenging medical problem for long-term care providers occurs when a resident undergoes an acute change in function due to a medical problem such as fever, a fall, an exacerbation of arthritis, or syncope. Such problems require rapid assessment by a skilled professional, because progressive worsening and/or the development of permanent impairment can occur rapidly in this frail population. Ideally, the following services should be available to help manage such situations: a rapid on-site evaluation by a physician, nurse practitioner (NP), or physician's assistant (PA); portable X-rays, electrocardiography, and laboratory testing, with results sent by fax transmission to the facility; and, if hospitalization is needed, an electronic record system that allows for seamless transfer of information between the facility and the acute care setting.

Physician Services

Families of long-term care residents are often surprised at how infrequently physicians visit and assess the residents. Medicare and Medicaid require one physician visit per month for persons undergoing nursing home rehabilitation, one physician visit every 2 months for other nursing home residents, and one physician visit every year for residential care/assisted living residents. More frequent visits are reimbursed only when a specific medical problem is documented to need more than routine care. Given the burden of illness in the long-term care population, this arrangement necessitates a high level of autonomous assessment by nursing staff, and much communication between the facility and the physician. As a result, numerous daily fax and telephone communications between the facility and physicians are the norm, and at times create undue burden for both. There are several other unresolved issues related to physician services in long-term care, as well. One debates whether or not it is preferable to have a small number of physicians, who serve as long-term care specialists, provide the majority of the care. Another issue is whether, and to what extent, the quality of care is improved by having an NP or PA. Most data to date suggest that both of the above care arrangements do improve the quality of care. Other, less well-researched issues involve the importance of continuity of care in this setting, and whether it is preferable to have care rendered in the physician's office or on-site in the facility.

End-of-Life Care

With high proportions of older adults living in long-term care, it should come as no surprise that increasing numbers of older adults are dying there, as well. In fact, as many as two-thirds of nursing home residents die there rather than in hospitals or private homes. Overall, the proportion of US deaths occurring in long-term care is 23%, and it is expected to increase to 40% by the year 2040. One of the issues relevant to end-of-life care in long-term care is the presence and adequacy of available medical services. As noted previously, physician presence is

not common in either setting, and long-term care providers may not be sensitive to changes in resident status that suggest impending death and so indicate the need for palliative care. Similarly, when families are not present on a daily basis, it is challenging to know when to contact them so as to assure their presence at the time of death. Fortunately, these types of issues are receiving attention, and one historic limitation of end-of-life care in long-term care – insufficient use of hospice – seems to be resolving.

Family Involvement

It is the norm rather than the exception that older adults who live in long-term care settings were cared for by family before their admission, and that caregiving does not end after admission. In fact, families visit residents an average of twice a week, for approximately 4 hours. They constitute an important resource to staff because they have knowledge of the resident's history, and they are important to the resident for emotional connectedness and psychosocial health. Indeed, family presence improves resident psychological and psychosocial well-being, as well as the accuracy of diagnoses and thus the resultant care. Also, family members are called upon to make decisions regarding care for cognitively impaired residents and to provide continuity that may otherwise be lacking due to staff turnover. However, the value of family members as a resource in long-term care is only beginning to be realized, and efforts have begun to consider how to integrate them into the fabric of long-term care provision – albeit while not overburdening them and creating tensions.

Staffing

The long-term care workforce is one of the major challenges to the provision of consistent, high-quality care. Already, the workforce is in short supply of crisis proportion, a problem that promises to worsen as the population continues to age. Between 2000 and 2030, the demand for paraprofessional workers (referred to as nursing assistants in nursing homes and as personal care aides in residential care/assisted living) will increase by 200% as the Baby Boomers reach age 85. In contrast, the supply of these workers is expected to increase only modestly: projections indicate that the availability of direct care workers will grow by approximately 2% in nursing homes and 5% in residential care/assisted living per year between 2000 and 2010. Because these paraprofessionals provide 80–90% of the direct care, they constitute a crucial component of the workforce. Coupled with an insufficient number of staff are turnover rates exceeding 100%, reflecting the poor pay, challenging work, and scarce rewards that accompany this job. Turnover compromises the quality of care and is costly to facilities already struggling to provide optimal care with fixed resources. Considering the expenses of overtime pay, hiring outside agency staff to cover shortages, and the time required for training, the cost of replacing a worker averages three to four times the monthly salary of the employee being replaced. More important, however, is the effect of turnover on the quality of care and the unfortunate fact that those workers who are the most motivated and capable are the most likely to leave for better jobs elsewhere.

Abuse and Neglect in Long-Term Care

Residents of long-term care facilities are especially vulnerable to abuse, due to their physical and cognitive limitations, dependency on others, inability to report abuse or neglect, and fear that if they do, their reports may result in retaliation or other negative consequences. While there are no good estimates as to the prevalence of abuse in long-term care, there is evidence to suggest that it is a notable problem. There is also evidence that abuse is inflicted not only by staff on residents, but also by residents on staff (such as pushing, shoving, and slapping during receipt of personal care) and by residents on residents. Landmark work convincingly indicates that the prevalence of staff abuse toward residents in long-term care is not related to facility characteristics such as size or proprietary status, nor to staff characteristics such as age, education, or experience. Instead, it is the quality of staff–resident interactions that predict abuse. This is not to say that the staff want to have poor relations with the residents; on the contrary, most workers choose long-term care because they want to help older adults. Unfortunately, staffing shortages necessitate that relationship building and maintenance take a back seat to performing visible and immediate tasks, such as making beds and changing soiled clothing – clearly, not the type of work that enticed the staff into this field. In fact, workers typically have only 15 min a day to actually talk with residents.

The Quality of Care

Problems in care have plagued the long-term care system for decades, and continue; for example, untreated pain, reports of neglect and abuse, medication errors, and urinary incontinence have been identified as recent and ongoing problems. Some of the problems in the quality of care relate to staffing. Staff turnover is associated with poorer resident function and increased risk of resident infection

and hospitalization. The exact mechanism through which care is affected is unknown, but it is suggested that turnover impedes training and supervision and reduces the familiarity between staff and residents that is central to detecting change in resident status and incident events. Other staffing factors that relate to the quality of care include training (the requirements of which are minimal), temporary versus permanent assignment, staffing ratios, and staff–resident relationships. Of course, some of the problem also relates to the nature of long-term care itself: it provides care for frail and chronically ill residents and does so with limited resources. Overall, however, the quality of long-term care is gradually improving. Rates of preventable problems, such as decubitus ulcers, are declining; awareness and appropriate treatment of dementia is increasing, along with reduced use of chemical and physical restraints; newly built facilities are more attractive than those built decades ago; and private rooms and bathrooms are more common. Some of the credit for improved care is due to the Nursing Home Reform Act of 1987, which specified, in part, a resident-focused, outcome-oriented survey process and a standardized assessment and care-planning process known as the Resident Assessment Instrument (RAI). A version of the RAI has been developed for residential care/assisted living, but as this setting does not have federal oversight, its use is optional, and it is not widespread.

Culture Change

Despite the advances that have occurred, consumers and providers of long-term care remain dissatisfied with many aspects of the present system. Within the long-term care industry itself, a growing movement believes that new models of care that focus more on resident quality of life within the context of quality of care are necessary and possible. These efforts include a greater emphasis on consumer involvement, the growth of residential care/assisted living, increasing attention to physical environments, and efforts to bring about 'culture change' – care that is person-directed and focused on caring for people and relationships, rather than on the task of care provision. Spearheaded by a small but growing group of providers, culture change is a grassroots movement that seeks to develop new, more resident-centered models of care through empowerment of both residents and front-line staff. Among the innovations promoted by culture change proponents are smaller, decentralized facilities, involvement of nursing assistants in all aspects of decision making and care planning, offering more choices to residents (e.g., dinner buffets), and individualized approaches to bathing and other activities of daily living.

Trends in Long-Term Care

A number of societal forces characterize and will guide changes in long-term care during the coming decade. Demographic factors, combined with changing societal attitudes, will lead to both an increased need for long-term care and a desire for more varied and higher-quality forms of care. Chief among the demographic changes are the aging of the Baby Boomers, many of whom are currently serving as caregivers for parents and are also beginning to enter the retirement years, and the nation's increasing multiculturalism. In addition, advances in health care are leading to the survival of significant numbers of persons with congenital disorders and chronic illnesses and to increased numbers of persons living to advanced ages. In part as a result of the aging of the Baby Boomers, attitudes toward long-term care are beginning to change. While the public, the media, and to some extent the research and regulatory communities continue to concentrate on negative issues and outcomes related to long-term care, more general acceptance of the necessity of such care is beginning to emerge. With this acceptance, however, comes higher expectations, a desire for alternative housing options, and increased interest in consumer directedness and choice.

The face of long-term care will be affected by events within the health-care system, including innovations in medical practice and technology, changes in the organization and provision of care, workforce shortages, and trends in financing and regulation. Health care of people with chronic illness will continue to become increasingly complex and include heightened use of complementary care practices, more emphasis on quality of life, and the need to incorporate continuing breakthroughs in treatment. Advances in technology, such as robotics, informatics, standardized data, integrated electronic health records, and more clearly articulated low-tech interventions, will increase the effectiveness of long-term care staff. Additional new and innovative approaches to care will increasingly appear, building upon what is already occurring through the culture change movement, various forms of residential care/assisted living, other residential models of care, and greater use of home- and community-based services. Against this backdrop of progress in the ability to provide care will remain major challenges to care provision, including the aging of the existing physical structures of nursing homes, tensions between

clinical and social models of care and between safety and autonomy, and workforce shortages.

The increasing long-term care needs of the growing population and the potential for the field to become more sophisticated will not necessarily translate into increased allocation of resources, however. It is widely believed that the recent growth in health-care costs is not sustainable and that there will continue to be funding cutbacks and further drift toward a disparate system of care based on ability to pay. A countervailing trend, however, is that of increasing openness to innovation on the part of the Center for Medicare and Medicaid Services (CMMS). This openness has in part taken the form of involvement of the Quality Improvement Organizations (QIOs) in long-term care, including a major emphasis on encouraging person-directed care during 2005–07.

Thus, the field of long-term care is undergoing rapid and exciting change. Use of service is high, and certain to grow. The quality of care is being tackled through significant activities of individuals and groups on the practice, regulation, and research fronts. These concerted efforts are sure to result in ongoing improvement, toward the ultimate outcome of improved quality of life for future cohorts of long-term care residents throughout the nation.

See also: Abuse and Neglect of Elders; Caregiving and Caring; Death and Dying; Health Care and Services; Hospice; Medicare and Medicaid and Economic Policy of Health Care.

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Longitudinal Studies

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Glossary

Age-Homogeneous Studies – Studies in which single or narrow age birth cohorts are sampled.

Ergodicity – Age differences between individuals and age changes within individuals are equivalent.

Longitudinal Design – A study that measures characteristics of the same individuals on at least two, but ideally more, occasions over time.

Introduction

A study with a longitudinal design is one that measures characteristics of the same individuals on at least two, but ideally more, occasions over time. Longitudinal studies are essential for understanding

aging-related changes because, in addition to providing information about between-person differences, they permit direct analysis of within-person change over time. An emphasis on understanding aging in terms of within-person changes is required for making valid inferences about aging-related changes.

Importance of Longitudinal Studies

Remarkable efforts around the globe have produced numerous major longitudinal studies of individuals 50 years of age and older. These represent an enormous wealth of information on within-person changes with age. Longitudinal studies are expensive in terms of both time and money, but they provide many significant advantages relative to cross-sectional studies and contain information relevant to significantly more levels of analysis. The between-person age comparisons that come from cross-sectional data cannot provide a basis for disentangling changes due to aging from, for example, stable individual characteristics, average between-person age differences, population selection, or mortality effects. Within-person change information is available only in longitudinal data. Recent developments in statistical methods facilitate the direct analysis and modeling of these within-person changes over time. Whereas several challenges to doing this persist, including the effects of repeated testing and population inference that take proper account of attrition and mortality, the latter remain inaccessible in a cross-sectional framework.

Potential Levels of Analysis in Longitudinal Research

For understanding aging, longitudinal studies provide many advantages compared to cross-sectional studies. Longitudinal data permit the direct estimation of parameters at multiple levels of analysis, each of which is complementary to understanding population and individual change with age. Whereas cross-sectional analyses permit between-person analysis of individuals varying in age, longitudinal follow-up permits direct evaluation of both between-person differences and within-person change.

Information available in cross-sectional and longitudinal designs can be summarized in terms of seven main levels of analysis and inferential scope. These can be ordered, broadly, in terms of their focus, ranging from the population to the individual. The time sampling generally decreases across levels of analysis, from decades for analysis of historical birth cohort effects to days, minutes, or seconds for individual-level processes such as within-person change, variability, and covariation (e.g., stress and health).

These levels of analysis are based on a combination of multiple-cohort, between-person, and within-person designs and analysis approaches, and all are represented by recent examples in gerontological research. Between-cohort differences (1), the broadest level, can be examined to evaluate whether different historical contexts (e.g., indicated by birth cohort) have lasting effects on level and on rate of change in functioning in later life. Population average trends (2) describe aggregate population change. They can be based on between-person differences in age-heterogeneous studies (confounded with cohort and selection/attrition/mortality) or on direct estimates of within-person change in studies with longitudinal follow-up, in which case they can be made conditional on survival. Between-person age differences (3) can be analyzed in terms of shared age-related variance in variance decomposition and factor models. This approach to understanding aging, however, confounds individual differences in age-related change with average age differences, cohort influences, and mortality-selection, among other effects.

Longitudinal models permit the identification of individual differences in rates of change over time (4), which avoids making assumptions of ergodicity – that age differences between individuals and age changes within individuals are equivalent. In these models, time can be structured in many alternative ways. It can be defined as time since an individual entered the study, time since birth (i.e., chronological age), or time until or since occurrence of a shared event such as retirement or diagnosis of disease. Elaboration of the longitudinal model permits estimation of between-person differences in within-person rates of change (5), in other words, using multivariate associations among intercepts and change functions in order to describe the interdependence of change functions. In shorter-term longitudinal designs, researchers have emphasized within-person variation as an outcome (6) and have examined whether individuals who display greater variability relative to others exhibit this variation generally across different tasks. Within-person correlations (7; i.e., coupling, dynamic factor analysis) are based on the analysis of residuals (after removing intraindividual mean and trend) and provide information regarding the correlation of within-time variation in functioning across variables. Each level of analysis provides only partial information regarding aging-related change, and the inferences and interpretations possible from any single level of analysis have distinct and delimited ramifications for

theories of aging. Each level provides complementary evidence for important characteristics of aging populations and individuals and provides alternative means for the development and evaluation of theories and models of aging.

Time Sampling and Alternative Longitudinal Designs

The levels of analysis described previously correspond roughly to different temporal and historical (i.e., birth cohort) sampling frames and range from longer to shorter intervals of assessment. The interpretation, comparison, and generalizability of parameters derived from different temporal samplings must be carefully considered and require different types of designs and measurements. The temporal characteristics of change and variation must be taken into account, as different sampling intervals will generally lead to different results requiring different interpretations for both within- and between-person processes. For example, correlations between rate of change over time in two variables will likely be quite different for short temporal intervals (minutes, hours, days, or weeks) compared to change across years, the typical intervals of many longitudinal studies on aging. Measurement interval is also critical for the prediction of outcome variables and for establishing evidence on leading versus lagging indicators. The typical design has relatively equally spaced intervals, with variance in spacing due largely to chance or to difficulty contacting participants. An alternative, the measurement burst design, in which repeated assessment bursts are obtained at each longer-term interval, is a compromise between single-case time-series and conventional longitudinal designs and permits the examination of within-person processes (within measurement burst) and change in processes (across measurement bursts) over time.

Chronological age (time since birth) is most commonly used to operationalize the construct of aging. Other approaches treat time as an ordinal variable (e.g., study wave) and model age as a covariate predicting individual differences in level and rate of change. However, we can also use alternative time structures in order to provide a more interpretable basis for individual change. For example, a longitudinal process-based model involves centering time on an event or state of a process of interest in order to compare individual change relative to a common organizing time structure. Such time specifications could be based on the occurrence of particular events or processes (i.e., morbidity, mortality; e.g., time prior to or since diagnosis of dementia or death). A key objective for any of these approaches is to distinguish changes as a consequence of aging processes from changes due to health or other change processes that are merely associated with age. This is similar to separating normative from non-normative influences. Whereas normative processes and events are strongly age graded and occur in all or nearly all individuals, non-normative processes and events are individual specific or subsample specific (i.e., the majority of individuals will not experience them) and tend to not be well predicted by chronological age. Structuring time based on non-normative events for subgroups of individuals permits analysis of change pattern and aggregate individual-level processes. Non-normative events are, by definition, low-frequency events, and are best evaluated in longitudinal studies with relatively long follow-up in order to capture the events and the preceding and subsequent change processes, concomitants, and predictors. Additionally, accounting for the myriad non-normative events permits, and is almost required for, an evaluation of normative patterns of change with increasing age.

Population Sampling, Attrition, and Mortality Selection

In observational studies, representative sampling is very important, as random assignment to conditions is not possible. However, attrition and mortality selection processes complicate both the definition of an aging population and the sampling procedures relevant to obtaining representative sample in studies of later life. Nevertheless, a major advantage of longitudinal studies is that they contain information necessary to examine the impact of attrition and mortality selection on the observed data. This information, ignored and inaccessible in cross-sectional data, is essential for valid inferences and improved understanding of developmental and aging processes.

Attrition occurs when an individual drops out of a longitudinal study. This can occur due to lack of time or interest, a residential move out of the study area (unrelated to the outcomes of interest), or failing physical or mental health. In many cases, the processes leading to non-response or attrition may not be of direct interest. For example, the moving away of participants from a longitudinal data collection project is unfortunate in terms of the study but is not necessarily related to study variables or participant characteristics, nor is it a natural result of developmental and population aging processes. However, attrition in studies of aging is often nonrandom (i.e., selective) in that it is likely to result from morbidity

and is likely to include declining physical and mental functioning of the participants over the period of observation. This is problematic because these are often the outcomes of direct interest.

Mortality is a distinct type of attrition because the definition of the population (i.e., all individuals currently living, conditional on age) changes with mortality. Population selection (i.e., mortality) is a natural population dynamic related to chronological age and a dynamic that is accessible only in longitudinal studies in which previous measurements have been obtained. In terms of population descriptions, inferences regarding change and causal processes may be obscured if mortality and selection processes are not properly taken into account, as such inferences must be made conditional on age and survival. It is important to note that the mortality selection dynamic cannot be understood in typical cross-sectional age-heterogeneous designs because such population sampling is based on single occasion sampling of survivors of different age and birth cohort groupings that have undergone differential mortality selection. Longitudinal data provide the opportunity to measure and address directly the processes of attrition and mortality selection – characteristics that define populations of aging individuals and that are necessary for understanding aging-related changes in health and cognitive outcomes conditional on both age and survival to particular ages.

Heterogeneity in terms of chronological age and survival poses analytical challenges for both cross-sectional and longitudinal data and is a particular challenge to studies that begin with age-heterogeneous samples. In studies on aging, the primary issue is that there is often no single well-defined target population but rather multiple populations that must be defined as conditional on both age and survival. Because attrition and mortality selection processes are inaccessible in age-heterogeneous samples, it is not possible to include these variables in a statistical model in order to obtain conditional estimates regarding populations defined by age and survival. A symptom of the challenges in age-heterogeneous sample selection is the fact that, at a particular age, it is easier to retain people with faltering physical or cognitive health in an ongoing study than it is to recruit them into a new study. As such, cross-sectional studies of older aged individuals will obtain more selective samples of this age range than longitudinal studies of the same age range that are ongoing from a younger age.

Age-homogeneous studies, in which single or narrow age birth cohorts are sampled, do provide an initially well-defined population that can be followed over time, permitting conditional estimates based on subsequent survival. Longitudinal follow-up of age-heterogeneous samples, the most typical longitudinal design, permits analysis of change over time but must be sensitive to the confounds associated with initial sample selection inherent in age-heterogeneous designs. In general, the analysis of longitudinal data on individual and population aging-related change processes can be properly evaluated and interpreted when the population parameters are estimated conditional on morbidity, mortality, and other attrition processes.

This lack of a single, accessible population in the data has consequences for the techniques for analyzing incomplete data. Whereas methods have been developed and are in relatively wide use in multilevel and structural equation modeling software, their application to longitudinal samples in late life remains problematic, both conceptually and computationally. These methods and their corresponding assumptions are based on the notion of a single, accessible population. At each new wave of a longitudinal aging study, however, the sample becomes less representative of the population from which it originated, and generalizations from the sample of continuing participants to the initial population become difficult to justify. Whereas some forms of non-participation can logically permit inference to a single population, such inference is impossible in the case of mortality because individuals have left the population of interest. Therefore, inferences regarding change must be defined as conditional on the probability of surviving or remaining in the study, in interaction with chronological age. In addition, the incomplete data mechanism in studies of aging is not likely to be missing at random (i.e., the probability of missing being dependent on measured covariates or prior states), an important assumption of current methods, because aging-related outcomes are known to be related to mortality and study non-participation.

Statistical approaches for dealing with mortality and ignorable non-response separately and that permit conditional separation of aging-related changes from other decline processes (mortality, disease-related change) are increasing in their application. Conditional selection related to mortality in longitudinal studies can be dealt with statistically in three ways: by ignoring missing values in maximum likelihood analysis, by modeling change conditional on a covariate representing mortality status or a time-varying covariate representing years to death, or by simply treating the data as complete within age-defined blocks of survivors. These methods alleviate some of the concerns with current state-of-the-art approaches for the analysis of incomplete data that

provide inferences to a single population of aging individuals.

Effects of Repeated Testing

Retest (i.e., practice, exposure, learning, reactivity) effects have been reported in a number of longitudinal studies on aging that focus on cognitive outcomes. The concern is that estimates of longitudinal change that might otherwise indicate decline may be attenuated due to gains resulting from repeated testing and potentially persisting over long intervals. Complicating matters is the potential for improvement to occur differentially, related to ability level, age, or task difficulty, which may be due to any number of related influences, including warm-up effects, initial anxiety, and test-specific learning, such as learning content and strategies for improving performance. Differential retest gains confound the identification of differential age-related changes (e.g., in older adults, retest may not be manifest as an increase in performance, but as an attenuated decrease in performance).

Although several statistical and design solutions have been proposed, conceptual difficulties arise in the consideration of whether retest or learning effects are a problem that can be solved statistically. Learning is a fundamental feature of repeated testing and of development in general and reflects important individual characteristics, relevant to aging and long-term change. Conceptual issues arise when learning effects are treated as nuisance parameters or artifacts of the study design. At the individual level, is it reasonable to correct an individual's change slope to what would have been obtained if repeated testing had not been performed? And if such a correction is reasonable, how should the slope be corrected? In most longitudinal sampling designs, exposure to test and within-person age are perfectly confounded, necessitating the use of between-person age differences to anchor the aging effects. Whereas retest effects are essentially within-person changes, this method of statistical identification leads to inferences regarding aging drawn primarily from between-person differences. In general, design-based and statistical approaches for dealing with retest effects rely on the performance of previously untested individuals who differ in age or birth cohort. This yields results that are strongly weighted toward cross-sectional estimates of age differences rather than within-person change and, therefore, suffer from the problems associated with age-heterogeneous sampling and selection issues.

Alternatively, retest effects might be considered an outcome of interest, with evaluation focused on changes in learning processes over time and emphasis on relative comparisons across individuals with similar testing experiences. Widely spaced occasions of measurement, typical of many longitudinal studies, may not be conducive to this perspective of learning as outcome, which requires intensive measurement bursts spaced over longer periods. Considering long-term change as conditional on previous testing experience certainly complicates inference to aging-related changes, with the potential for interaction of age, ability level, prior exposure, and retest effect. However, treating retest or learning effects as predictors or outcomes may provide a more realistic framework for understanding change in constructs influenced by learning gains, making use of individual differences in short-term gains for the prediction of long-term changes.

Generalizability across Cultures and Cohorts

Currently, published results from longitudinal studies are largely based on different analytic approaches, restricted or selective reports of results, and outcomes and covariates that differ in measurement instrument or coding procedure. Such differences hinder comparison of results across studies and limit attempts to assess generalizability. Focused efforts for data integration and evidence synthesis based on optimally comparable cross-study results would be a powerful addition to longitudinal work in aging, in which replication of previous studies may be more difficult. Collaborations across research teams will lead to the harmonization of measurement operations and development of common analysis protocols in order to maximize comparability, permitting both synthesis of results and sensitivity analysis within and across studies.

Overview of Existing Longitudinal Studies

Table 1 lists a sample of major longitudinal studies on aging selected on the basis of the availability of information on cognitive, physical, and mental health on more than two occasions (or with a plan for more than two occasions). Though each involves collection of data on similar constructs, these longitudinal studies fall into three main groups: large-scale epidemiological or survey studies, more focused psychologically based studies, and more intensive medical studies. The former are more likely to have a population-based sample but less in-depth measurement, for example, including little more than a screening measure of cognitive function, whereas the smaller studies are more focused on detailed measurement in their respective areas. Virtually all at least

Table 1 Longitudinal studies on aging with cognitive, demographic, health, lifestyle, and psychological data

Study title	*Start year*	*n (T1)*	*Age (T1)*	*Follow-up (years)*[a]	*Occasion interval (years)*	*Current number of occasions*	*Sample type*
Aging in Manitoba	1971	8950	60+	30	5 to 12	5	Stratified random sample
Asset and Health Dynamics among the Oldest Old	1993	7447	70+	9	2	6	HRS screening sample, Medicare enrollment, minority oversample
Australian Longitudinal Study of Aging	1992	2087	70+	13	1–3	8	Stratified sample of community dwelling and institutional care facilities
Baltimore Longitudinal Study of Aging	1958	260	20–96	46	2	24	Volunteer (men only pre-1978)
Berkeley Older Generation Study	1968	94	59–79	14	14	2	Participants of Berkeley Growth and Guidance Studies
Berlin Aging Study	1990	516	70–100+	15	2–4	7	City Register, Former West Berlin
Betula Project	1988	3500	35–80	10	5	3	Stratified
Caerphilly Cohort Study of Older Men	1979	2512	45–59	25	4, 5	6	Electoral register plus GP lists, male only
Cambridge City over 75 Cohort Study	1985	2616	75+	20	1	20	Population based
Canadian Multicentre Osteoporosis Study	1996	9423	25+	5	1	6	Random sample
Canadian Study of Health and Aging	1991	10 263	65+	10	5	3	Representative sample with oversampling of very old
Canberra Longitudinal Study	1990	897	70–93	12	3.5	4	Community sample (electoral role), institutional care, oversampling of very old
Cardiovascular Health Study	1989	5888	65+	10	1	10	Medicare eligibility list, noninstitutionalized, no proxy needed
Duke Longitudinal Study of Normal Aging[b]	1956	267	60–94	21	8 months–4 years	11	Volunteer
Duke Longitudinal Study of Normal Aging II	1968	502	45–69	8	2	4	Volunteer
Einstein Aging Studies	1980	488	70–90	20	1	20	Volunteer sample
English Longitudinal Study of Aging	2002	12 100	50+	2	2	2	Representative of 50+ English population
Established Populations for Epidemiologic Studies of the Elderly	1981	14 456	65+	12	2	7	Random, cluster and stratified sampling

Fredericton 80+ Study	1998	387	80	6	1	7	Population based
Gender Study of Unlike-Sex DZ Twins	1995	500	69–81	8	4	3	Opposite sex twins in Sweden born between 1906 and 1925
Gerontological and Geriatric Population Studies in Göteborg, Sweden	1971	1000	70	30	4, 5	12	Representative
Groningen Longitudinal Aging Study	1993	753	57–99	2	1	3	Patient population with physical limitations
Health and Retirement Study	1992	12 600	50–60	12	2	7	National sample, minorities oversampled
Health, Aging and Body Composition Study	1997	3075	70–79	6	1	7	
Healthy Older Person Edinburgh Study	1990	597	70+	4	4	3	Medical registry
Honolulu-Asia Aging Study	1991	3734	71–93	6	3	3	Japanese men only
Interdisciplinary Longitudinal Study of Adult Development	1996	1384	45, 65	8	4	3	Former East and West Germany
Italian Longitudinal Study on Aging	1992	5493	65–84	8	3, 5	3	Population-based
Kungsholmen Project	1987	327	75+	12	2 to 4	5	Population from Kungsholmen district, Stockholm
Long Beach Longitudinal Study	1978	509	55–87	21	Varies	4	Recruited from Health Maintenance Organization
Longitudinal Aging Study Amsterdam	1991	3107	55–85	9	3	4	Urban and rural municipal registries
Longitudinal Studies of Cognitive Change in Normal, Healthy Old Age	1982	6187	49–96	14	Varies	4	Community volunteer
Lund 80+ Study	1988	211	80+	10	5	3	Population of Lund 80+ years old
Maastricht Aging Study	1992	2000	24–81	6	3	3	Recruitment from Registration Network Family Practices
McArthur Studies of Successful Aging	1988	1192	70–79	3	3, 4	3	Selected from three cohorts of Established Populations for Epidemiologic Studies of the Elderly

(*Continued*)

Table 1 (*Continued*)

Study title	*Start year*	*n (T1)*	*Age (T1)*	*Follow-up (years)*[a]	*Occasion interval (years)*	*Current number of occasions*	*Sample type*
Medical Research Council Cognitive Function and Ageing Study	1991	13 000 +	65–75	12	1–3	8	Multicenter; randomly selected from Family Health Services Authority lists
Monongahela Valley Independent Elders Survey	1987	2002	65 +	15	2	8	Rural community
Nordic Research on Aging	1989	1204	75	5	5	2[c]	Representative city samples
Normative Aging Study	1963	2280	21–81	42	5	13	All male community sample
Nottingham Longitudinal Study of Activity and Ageing	1983	1042	65 +	8	4	3	Electoral ward and family practitioner committee lists
Nun Study	1991	678	75–103	9	1.5	6	American School Sisters of Notre Dame
Octogenarian Twin Study	1990	702	80 +	8	2	5	Swedish Twin Registry
Ontario Longitudinal Study of Aging	1959	2000	45	31	1	30	Men only, stratified quota
Personnes âgées QUID?	1988	4134	65 +	13	1-3	6	Three cohorts: 1988 and 1989 age, sex stratified, community dwelling; 1990 institutionalized
Rotterdam Study	1990	7983	55 +	7	3, 4	3	Population based
Seattle Longitudinal Study	1956	5000	22–70	42	7	7	Health Maintenance Organization
Southampton Aging Project	1977	340	65 +	20	10, 2–3	8	Random sample from two general practices
Swedish Adoption/ Twin Study of Aging	1984	1500	40–84	6	3	3	Swedish Twin Registry
Swiss Interdisciplinary Longitudinal Study on the Oldest-old	1994	714	80–85	10	1.5	9	Stratified (age/sex), initially community dwelling, urban and rural
Victoria Longitudinal Study	1986	1584	55–86	12	3	5	Community volunteers
Wisconsin Longitudinal Study	1957	10 317	18	48	7 to 17	5	Random sample high school graduates

[a] Total follow-up as of year 2005.
[b] Life style data not available.
[c] Only two occasions planned.

touch on the areas of sociodemographics, physical and psychological health, cognitive function, and activity/lifestyle, though there is a large amount of variability in the detail with which the different areas are measured. Some of the longest running studies are approaching 50 years of follow-up. A number have more than 10 occasions of measurement. One has as many as 30. Currently, the available information in most of these studies far exceeds what has reached publication. With continued developments in the methods to analyze these data, and with concerted efforts to make use of the available information, this wealth of data holds the potential to greatly contribute to the development of theories of aging and a basis for intervention and prevention efforts.

Summary

Longitudinal studies have direct implications for explanatory theories of development and aging. Evidence obtained thus far from long-term longitudinal and intensive short-term longitudinal studies indicates remarkable within-person variation in many types of processes, even those once considered highly stable (e.g., personality). From both theoretical and empirical perspectives, between-person differences are a complex function of initial individual differences and intraindividual change. The identification and understanding of these sources of between-person differences and of developmental and aging-related changes require the direct observation of within-person change available in longitudinal studies.

There are many challenges for the design and analysis of strict within-person studies and large-sample longitudinal studies, and these will differ according to purpose. The challenges of strict within-person studies include limits on inferences given the smaller range of contexts and characteristics available within any single individual. Of course, the study of relatively stable individual characteristics and genetic differences requires between-person comparison approaches. In general, combinations of within-person and between-person study designs are necessary for comprehensive understanding of within-person processes of aging because people differ in their responsiveness to influences of all types and the breadth of contextual influences is unavailable in any single individual. The strength of the many existing longitudinal studies is that they permit the simultaneous examination of within-person processes in the context of between-person variability, between-person differences in change, and between-person moderation of within-person processes.

See also: Comparative and Cross-Cultural Studies; Generational Differences: Age-Period-Cohort; Research Design and Methods.

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Markers of Aging

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Glossary

Biomarker – A term for a descriptive or predictive variable intended to measure some aspects of some aging processes.

Gerometric – Biometric, psychometric, and sociometric applications to gerontology.

Reliability – The proportion of variance in a measured variable that is attributable to variance in true scores as contrasted to error variance.

Validity – The degree to which a measured variable represents the construct that it is intended to represent.

Introduction

The term biomarker, which is encountered with increasing frequency in the gerontological literature, is used with a variety of implicit or explicit definitions. In some contexts, a biomarker is expected to predict longevity; in other usages, it is expected to be correlated with physiological age; in still other, it is expected to be descriptive of a fundamental aspect of aging, and so on. This breadth of usage is so great that an argument can be made that the phrase, 'biomarker of aging' is simply synonymous with 'age-related variable'.

When understood in this broad sense the only advantage of the label biomarker over the term 'variable' might be the specific emphasis on biology provided by 'bio' and the reminder provided by 'marker' that the variable in question is a proxy or surrogate variable. In the final analysis, whether it be labeled biomarker or age-related variable, it is being used because one cannot measure biological age or aging directly.

In some contexts, the term biomarker is employed in a more restricted sense to refer specifically to variables being used in a multivariate attempt to define biological or functional age. In another, specialized usage, the biomarker label is reserved for outcome variables appropriate to assess the efficacy of an intervention designed to affect some aspect of aging processes. The desirability of a standard reference set of biomarkers in the letter sense has motivated a major program initiative of the National Institute on Aging.

In a recent evaluation of biomarkers, Arking has provided the following (paraphrased) list of desiderata, which may be regarded as a representative summary of current thinking in the field. Biomarkers should

1. Change with time at a rate that reflects the rate of aging,
2. be monitoring some basic, important process,
3. be non-lethal, and preferable non-invasive and minimally traumatic,
4. be highly reproducible,
5. reflect physiological age,
6. display change over a relatively short period,
7. be crucial to the maintenance of health,
8. be measureable in a variety of species,
9. serve as a predictor of life span, and/or
10. serve as a retrospective marker of aging.

As a further summary, it might be suggested that the desired attributes of biomarkers fall into three classes: pragmatic, ethical, and methodological. Pragmatically, biomarkers should be simple and inexpensive to measure. Ethically, they should be minimally intrusive, causing the least possible pain and stress. Methodologically, it is desirable that they be non-destructive (permitting longitudinal research); capable of demonstrating change over a relatively short portion of the life span; insensitive to effects of previous measurement; and robust over a large range of laboratory and experimental conditions. Of utmost importance is that they measure aging validly and reliably. The meaning of this last statement engages subtle issues, some of which will be elaborated later.

The Diversity of Biomarkers

In the broadest usage described above, every attribute measured in a study of aging could reasonable be regarded as a biomarker. The range of applicability is nearly as great when more constrained definitions are used. In a conference reviewing the state of research at the onset of the biomarker initiative of the National Institute of Aging, genetic, molecular, cellular, tissue, and whole-organism variables were discussed. A few years later, the First International Congress on Biomarkers of Aging: Expression and Regulation was convened. Titles from the proceedings of that congress reveal a similarly wide array of measures. A sample of the domains within which putative biomarkers were investigated include neuroendocrine systems, degradation of altered protein molecules, lateral mobility of cell membrane proteins, DNA repair, molecular myocardial changes, membrane cholesterol, blood–brain barrier permeability, immune system alteration, heat shock proteins, activity levels, and cognitive functioning.

In a book on preventive intervention oriented to ward the general reader, Evans and Rosenberg identified the following as pertinent biomarkers: muscle mass, strength, basal metabolic rate, body fat percentage, aerobic capacity, blood sugar tolerance, cholesterol or high-density lipoprotein (HDL) ratio, blood pressure, bone density, and ability to regulate internal temperature.

Obviously, neither a comprehensive review nor an evaluation of the degree to which each of these biomarkers meets the specified criteria is within the scope of the present article. What follows is, therefore, a discussion of some principles that have general applicability.

Biometric Considerations

The definitions of biomarkers are quite varied, but all refer in one way or another to the measurement of age or aging. An appreciation of the purposes and requirements of biomarkers requires consideration of some basic issues of measurement in gerontology. Obviously, biomarkers must meet the same biometric, psychometric, and sociometric requirements as any other variable in biological, behavioral, or social sciences. In the dynamic context of change in aging there are some special, gerometric issues.

Limitations of Chronological Age as a Metric in Gerontological Research

At a cursory glance, gerontologists might be thought to possess a superb measurement instrument in the form of the calendar, for it is possible in principle to determine the chronological age of most human beings and animal subjects to a high degree of accuracy. For some purposes, this sample statement of chronological age – the number of days, months, or years that the individual organism has been alive – may suffice. For example, if the geronotological question concerns the relative longevity of different species, the relevant information may be provided by the average ages at death of people and mice, for example. Such facts of species differences in life span engage fundamental issues of evolution. For many purposes, however, calendar age is an unsatisfactory index, principally because, within species, individuals of the same chronological age may differ markedly in respect to a number of attributes that we associate with the aging process. Thus, there must be a process(es) at work that is somewhat, but not too closely, related to the passage of time, but that differs from individual to individual. To assign the same age value to a number of individuals, all of whom where born on a particular day in 1920, say, would omit information on the huge differences existing among them in functional competence, cognitive performance, memory capability, glucose tolerance, aerobic capacity, pulmonary functioning, cardiovascular health, body composition, and so on.

The facts of intraspecific variability in aging processes are of basic biological interest equal to those of interspecific differences. These individual differences are, of course, central to societal concern over the health and welfare of an aging population; it is expected that elucidation of the determinants of individuality in rate and pattern of aging will powerfully inform efforts to promote 'successful aging' and extend the healthy life span.

If, as we have seen, individual differences reduce the descriptive and predictive value of chronological age, then measures must be employed that are capable of characterizing the individual differences of these features. The functional age of an organism may then be considered to be its relative rank among comparable individuals of the same chronological age with respect to these measures. Aging comes to be defined then, as change with respect to these measures as a function of chronological time. The crux of the matter becomes the section of measures, or, it may be said, of biomarkers of age and aging.

Validity: What Does a Biomarker Measure?

Perhaps the simplest definition of the concept of validity is that it is an index of the extent to which any empirical measure actually measures what it is alleged to measure. Under some circumstances, the entity or property under investigation could actually

be measured directly, but the measure used is a substitute (or proxy, or surrogate, or marker, or indicator) for it. In some cases, the marker is employed rather than the real thing because the marker is more convenient or less expensive. Though it might require considerable effort in practice, the determination of validity in these instances is conceptually straightforward. The concurrent validity of the marker can be evaluated by obtaining the correlation between it and the definitional 'real thing' measured at the same time.

In other cases, the real thing will only exist in the future, and the objective is to predict it from the surrogate measurement. A familiar example of the latter situation is the attempt to predict success in college or in graduate school from standardized tests. Determining the correlation between the marker variable and the outcome variable (when it later becomes available) is described as the predictive validity of the marker. Validity of this type is implied by the above-cited definitions of aging, which refer to the ability to predict longevity as a major criterion of biomarker status. Indeed, some investigators maintain that longevity is the ultimate validity criterion for a biomarker. A major difficulty in accepting age at death as the defining variable in gerontology is the loss of information concerning the highly variable differences in trajectory and pattern by which individuals arrive at the point of death. Thus, whereas longevity has high 'face validity' (on the face of the matter, it seems that length of life must be related to aging), any claims that it enjoys superordinate status as the fundamental validity criterion for biomarkers of aging must be carefully and skeptically examined.

Circumstances abound in the life sciences where explanation invokes hypothetical constructs for which no single, unambiguous measure is consensually accepted by scientists as telling the truth, the whole truth, and nothing but the truth, about it. For constructs of this nature, of which age and aging are widely regarded as examples, there are several approaches to assessment of validity. Content validity, for example, refers to the extent to which a measure (or panel of measures, collectively) samples the domain under investigation. Obviously, to judge content validity, one requires an already highly developed understanding of the domain itself. Another approach is that of construct validity, which is the extent to which the biomarker behaves as predicted by formal theory or by expectation derived from a coherent body of empirical data. For example, although the limitations of chronological age have been discussed, it certainly appears that a valid biomarker of aging should have some relationship to it. Traditionally, this age relevance has been sought in the form of mean differences among groups of different chronological age, or of mean changes in longitudinal studies. The examination of mean values in this context is conceptually direct, but may overlook data of great value. For some purposes, systematic change in variances, covariances, kurtosis, and skewness should qualify a purported biomarker as age-relevant as definitively as would the conventional change in means.

From the perspective of construct validity, it might also be expected that a nominated biomarker of age should respond appropriately to an intervention, such as dietary restriction, which has been shown to increase life span. One problem in applying this criterion arises from the complexity of aging, discussed in more detail below. Different subprocesses of aging may proceed relatively independently and may be differentially susceptible to interventions. For example, research has shown that an antiaging treatment beneficial in one genotype may be harmful in another. Thus, legitimate measures of some aging processes in some animals might be rejected as biomarkers if tested with a different group of subjects. This observation epitomizes the general principle that the validity of a model system is a function not only of the biomarker employed, but also of the total context of its measurement, including the genotypes of the animal subjects.

Generalizability of Animal Model Results to Humankind

The types of validity discussed above concern the extent to which the measurement of some attribute of, for example, a mouse, is really assessing what it is intended to, in the mouse. In research that has the ultimate goal of illuminating aging processes in humankind, there is another level of concern about validity – the generalizability across the phyletic scale from animal model to human beings.

For some biomedical phenomena, the homology of human to animal condition may be apparent – blood pressure, glucose tolerance, renal function, muscle anatomy, body composition, immune system parameters, and so on. Even in these cases of high 'face' validity of the animal model, however, there are often subtle differences that must be carefully evaluated.

In the realm of behavior the homology of animal to human phenotype is usually more difficult to demonstrate. The mouse equivalent of a test of fluid cognitive ability is not obvious, for example. However, this difficulty should not be regarded as totally prohibitive. Typically, the hope in utilizing the animal model is that there exists in the animal some system that has properties sufficiently similar to the human system that the former will be informative

about some aspects of the latter. Of particular relevance to the topic of behavior are the parallels in the neurochemistry and neuroanatomy of humankind and research animals that have contributed immensely to the current understanding of the workings of the central nervous system (CNS). The existence of these parallels in CNS function justifies reasonable expectations that animal models can be valuable in the study of human behavioral aging (*see* Models of Aging: Vertebrates).

Reliability of Measurement

A fundamental principle of measurement is that nothing can be measured with absolute accuracy. It is thus important to ponder the level of uncertainty associated with any biomarker measurement. The statistical model usually employed in such considerations posits the existence of a true value of the variate, with error-producing factors generating a normal distribution of measured values around the true value. That is to say, it is assumed that on any particular measurement occasion, for any given individual subject, there exists a real value of the attribute being measured. Inevitably, however, the measurement process will be affected by factors that cause the observed value to deviate from this true value. The model is particularly applicable when dealing with simple errors of observation – change in angle of view of a meniscus level, or parallax effects on a meter reading, or misscoring an item on a cognitive test, or misrecording of a value on a data sheet, or inaccuracy in mixing a solution. Within each discipline, standardized measurement protocols are intended to reduce such error. It is axiomatic that such error can only be reduced but cannot be eliminated.

Any particular single measurement must, therefore, be regarded as a single sample observation from a distribution of possible values. If the error distribution is narrow, then the number obtained on any one occasion of measurement will be close to the real, 'true' value. If the error distribution is broad, the measure obtained for a single individual on one occasion might be quite far from the true value, and the particular value obtained will not be a very accurate representation of the true state of affairs. An obvious tactic in such a case is to take multiple measurements; the mean of such series will be a more accurate estimator of the true value than will any single measurement. The direct course of action is not possible for many markers, however, which, by their nature, can only be measured once. The recourse usually sought is to shrug off the uncertainty about the precision of individual values and rely on reduction of the sampling error by employing larger numbers of subjects.

The general model of a true score with an error distribution is also useful in circumstances involving factors that influence the measurement outcome but cannot be regarded as genuine error. Consider a biomarker employed to test the efficacy of some intervention in a rodent model. In addition to the effects of the intervention variable, the biomarker might be influenced by season of the year, time of day, temperature, time since last meal, constitution of the diet, techniques of the technician, previous measurements, time since importation into the laboratory, and so on. Each of these factors is, by definition, an independent variable that has influence upon the dependent variable whose value is being sought. In another context, each of these factors might be the object of investigation in its own right, but in the particular research context they are considered to generate unwanted variability. Thus, they are identified as contributing 'error.' The existence of such factors is well recognized within each discipline, of course, and procedures for minimizing their influence constitute the methodological lore of controlled variables within the disciplines. Naturally, these control procedures are effective only for 'error' producers that are known.

There are logistical constraints on the amount of manipulated control that can be exercised in any experiment. Thus recourse to randomization is frequent. The effects of the randomized variables will add to the uncertainty generated by real error, increasing the aura of inconclusiveness to be associated with any empirically obtained measurement.

The concept of reliability addresses the issue of the proportions of variance in empirically obtained values that can be attributed to the variability of the true scores and to the magnitude of the error effects. If the locations of individuals in such an empirical distribution are mostly attributable to their true values, with little error (i.e., if the measurement is highly reliable), then a very similar distribution would be expected if all of them were measured again. The correlation of scores obtained on successive occasions is, in fact, one of the standard methods for estimating reliability.

Biomarkers as Elements of Complex Systems

Appropriately for so dynamic a field of inquiry, many issues of gerontology are unsettled. There is good agreement, however, that aging is a complex process or set of processes. The consensus is well represented by Baker and Sprott (1988: 231): "It is also quite

evident that there may be many processes of aging and that various systems (physiological, biochemical, and/or molecular-genetic) undergo alterations at differential rates."

It is apparent that a comprehensive view of aging will require representation of biological or functional age in terms of a complex nexus of interrelated variables constituting a system. Such a representation has important implications of what one can and cannot expect of biomarker variables.

Conceptual and analytical models for dealing with complex systems have long been the subject of intense intellectual effort. This effort has burgeoned in recent years, and considerations of complexity, dissipative structures, self-constructing systems, and so on, appear in an increasing range of both physical and life sciences. Yates and colleagues have urged and pioneered the application of systems principles to gerontological issues. It is probably accurate to observe, however, that gerontology has only begun to reap the benefits of systems perspectives.

A defining characteristic of a system is the interrelatedness of its elements. These interconnections can be hierarchical, with a one-way flow of influence. On the other hand, there may be feedback. Indeed, some sort of feedback is implied in any system or subsystem that is subject to homeostatic or other types of regulation. The feedback loop blurs the meaning of cause and effect and severely limits interpretations based upon models of Newtonian, unidirectional causality.

A major consequence of network causality is that the influence of any element of the system is context-dependent. Whether or not some particular factor is influential, even the direction of its influence, is dependent upon other elements in the causal network. It may be somewhat discomfiting to conclude, therefore, that the significance of a biomarker may differ from one individual to another. The case cited earlier by Harrison and Archer will serve as a useful example here as well: the efficacy of dietary restriction is dependent upon genotype.

Another clear implication of great importance for the present topic is that no one marker can characterize a system; searching for a marker for all purposes is futile and misguided. The image of blind men describing an elephant is rather overworked, but is particularly apposite. A comprehensive representation emerges only when the diverse perceptions of tail, trunk, legs, ears, and so on are collated and interrelated. Inevitably, gerontology will require increasing sophistication with, and use of, multivariate (multibiomarker) methods as the limited information from each individual biomarker contributes to our understanding of age and aging.

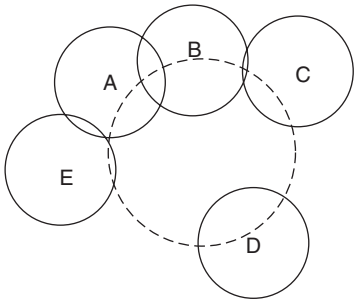

Figure 1 Partial representation of age or aging (dashed circle) by specific biomarker variables (solid circles labeled A–E).

It may be useful to reiterate by a Venn diagram as shown in **Figure 1**. Assume that the dashed circle represents all meaning of the concept of aging. No one has ever measured aging; they have simply been able to measure various manifestations of it. Assume a number of these operational measures of 'aging': A, B, C, D, and E, shown in the figure as closed circles. It may be seen that all of these biomarkers tap some part of the 'aging' system, and that none of them exhaustively assesses the total domain encompassed by the dashed circle. Furthermore, none of them measures only aspects of the domain; that is to say, some of the area of all of the closed circles lies outside the domain. (This means simply that there are things other than the aging processes that influence the biomarker.) Most measures are correlated (i.e., overlap) with others, but one (D) is completely independent. In one case (A and E), the correlation is only for elements outside the domain and is therefore meaningless with respect to aging. Relating this representation to the discussion of systems, it can be imagined that the degree of overlap of the Venn circles represents the extent to which the biomarkers share membership in 'causal' routes within the 'causal field.' Inclusion of all of these empirical measures in an assessment of 'aging' would tap much, but not all, of the total meaning of the concept. Some parts of the domain would be overmeasured, in that three of the measures overlap within the domain, but some would be left without representation.

Biological systems are usually composed of subsystems, often organized into hierarchies and subhierarchies. In a network or causal field of this sort, some elements will have more 'connectedness' than other, in the sense that relatively more than average of the other elements of the system are related to them. The hoary notion of the 'final common path' describes one type of such convergence of influences. Quite obviously, a biomarker that taps into such central 'soft spots' can likely contribute more richly to description, understanding, or prediction than can a less well-connected element.

Biomarkers in Changing Systems

A system of the type discussed above cannot be maintained statically, but only dynamically. Thus, if some element in the system is perturbed, processes are set in motion to return the element to a set point or set range. This system responsiveness is familiar as homeostasis. Variants of the idea involve set points that are changing in development processes (homeorhesis or programmed rheostasis) or in response to environmental factors (reactive rheostasis). In a complex network, any such dynamic action can have widespread ripple effects, with elements of the same subsystem oscillating for some time before settling down. The interactions of a living organism with its environment (including others of its species) assure that at least some subsystems will be in an almost continuous process of displacement from set range and recovery toward it. In addition to the problem of error and uncontrolled variable sources discussed above in relation to reliability of measurement, there is this additional problem that an effort to characterize a biomarker is faced with a moving target. A biomarker of a labile system such as this might give different values on measurement occasions hours or even minutes apart. Somewhat paradoxically, if perfect or near-perfect reliability (in the sense of high test–retest correlation) is required of biomarkers, labile systems, which may be of high biological relevance, will be exempted from examination (*see* Homeostasis, Homeodynamics and Aging).

Intervals of sufficient duration to permit the occurrence of aging changes require a distinction between reliability and stability. If all individuals change at the same rate in respect to some biomarker, then, providing that the measurement is reasonably reliable, their ordinal ranking on occasion $n+1$ will be about the same as that on occasion n, yielding a high correlation between occasions. If, however, there are individual differences in rate of change, the rank orders will differ on the two occasions, and the correlation will be attenuated, even though the biomarker is measured with high reliability. A high correlation between occasions will reflect both high reliability of measurement of the biomarker and stability of the aging process of which it is a marker. A low correlation between occasions may not be a condemnation of the biomarker from a gerometric point of view, but simply a reflection of individual differences in the pertinent aging subprocess. Rejecting candidate biomarkers because of low test–retest correlation across these longer intervals might foreclose on the examination of important processes.

In principle, it is remotely possible that all elements in the changing system would change in proportional ways in the same direction and at the same rate. Given the evidence for differential changes in age-related variables, this prospect is most unlikely for gerontologically interesting system. Thus one may expect that aging of a system will be characterized by changes in the interrelationships among elements in that system. Accepting that the meaning of a variable can only be described by its relationships to other variables, the simple but profoundly important implication is that the meaning of a particular biomarker variable can change over the life course. It might be describing central aspects of some aging subprocess at one stage of the life trajectory and be less related or even unrelated to that same subprocess at another stage.

In multivariate research, through such issues as degree of invariance in factor structure, the possibility of change in the meaning of a biomarker is thrust unmistakably to the fore. In univariate research, unfortunately, there is no obvious way to observe such a change. Ignorance of changes in biomarker meaning does not obviate their effects, however.

Scale

A generally ignored matter, but one of substantial methodological import, is the nature of the scale of measurement of the biomarker. Four types of scale are usually defined: normal, ordinal, interval, and ratio. The distinction among them is an important one because the type of statistical analysis that is justified depends upon the level of measurement that generated the data. For the lowest level of measurement – nominal – the data serve merely to identify individuals or to assign them to groups. Numbers on football jerseys are often pointed to as exemplars of the former application of a nominal scale. Assignment of individuals to the categories of male or female is an example of the latter usage. Assignment of numbers on a nominal scale is an arbitrary matter, and, indeed any distinguishing symbols will work equally as well as numbers. About the only statistical procedures that can be employed with nominal data are frequency analyses of various sorts.

For a scale to be ordinal, there must be an implication of 'greater than' or 'less than' associated with assigned numbers. For many, perhaps most, biomarkers in contemporary use, persuasive arguments can be made that this requirement is met. Qualifying as an ordinal scale permits the use of the median, percentiles, order correlations, and similar non-parametric statistical operations.

Unless a further criterion is met, however, one is not entitled to the use of means, variances, product–moment correlations, *t*-tests, analyses of variance,

and similar parametric statistics that constitute the bulk of statistical treatment in gerontological science. This additional requirement is that the numerical difference between two values of the scale should reflect the same magnitude of difference of the attribute being measured at all positions on the scale. A scale for which this attribute can be demonstrated is said to be an interval scale. Consider the phenotypic domain of mouse activity, of which numerous operational measures have been utilized as biomarkers of aging. The interval-scalar criterion requires that the difference in underlying trait being assessed (energy level, activity propensity, lack of inhibition, degree of fear, or some combination of these or other processes) between a score of 0 and one of 100 is the same as the difference in underlying trait represented between a score of 5000 and one of 5100. In cases where the biomarker is one of convenience, substituting for a more expensive or difficult-to-obtain gold standard measure, appropriate comparisons between the two measures may demonstrate this equality of intervals. For those cases where no such gold standard exists (and such cases must be the rule rather than the exception in the gerontological literature), then demonstration of interval-scale status may be very difficult, if not impossible.

An even higher status of scalar adequacy is that of ratio scales in which there must be, in effect, a meaningful zero on the scale. Under such circumstances, it becomes possible to make comparisons such as twice as much as, one-third as much as, and so on. For ratio scales, one can legitimately utilize coefficients of variation and geometric means. Ratio scales are very rarely encountered anywhere in biological, behavioral, or social sciences.

Lack of interval scale status may affect interpretation of life span differences or changes. Suppose that a change of x units in the lower ranges of a biomarker scale of 'vitality' represents a greater change in the underlying attribute than does the same numerical change higher on the scale. If older people tend to have lower mean values than do younger people, it is impossible to determine if a change late in life is equivalent in magnitude to one earlier in life. Rarely is the function known by which the numerical scale maps onto the underlying variable. Usually, then, and strictly speaking, only ordinal inferences are warranted when relating biomarker status to chronological age. These same considerations suggest the logical difficulty of assessing whether different individuals are changing at the same rate if they differ in mean value of the biomarker.

Addressing issues of this sort requires systematic attention to scale properties, but scalar adequacy criteria are not universally recognized. Even when recognized, explicit demonstrations of scalar adequacy are seldom undertaken. The empirical robustness of parametric statistics in the face of failure to meet interval scale criteria is not very well known in respect to specific biomarkers of aging; much of what is regarded as reliable information about them should, therefore, be regarded with some reservation.

Summary

This review of biomarkers has recognized that there are multiple meanings of the term, but argues that all usages engage two central questions of measurement, which might be informally phrased as follows:

1. What is being measured?
2. How accurately is it being measured?

The theme has been one of caution. It has been asserted that there is no gold standard definition of age or aging, for the philosophically crucial reason that no one knows what aging is, only certain manifestations of it. Any single biomarker, it has been argued, can measure only some (probably very small) part of the total meaning of age and aging. Furthermore, the numerical value obtained for a biomarker must be considered as an approximation, no matter how exquisite the care with which the measurement is made. How crude the approximation will be depends not only upon error but also on the parameters of the regulatory system that responds to displacement of the biomarker from its set range. Even more important, the fundamental meaning of a biomarker will depend upon the values of other components of the subsystem of which it is an element, will almost certainly differ therefore from individual to individual, and may change from one part of the life trajectory to another. In short, at the present stage of gerontological science, it is (1) difficult to say definitively what a biomarker measures, or what it should be measuring, and (2) any particular measurement outcome is surrounded by an aura of indeterminancy, the magnitude of which is usually unknown.

But it must be made clear that the limitations and shortcomings dwelt upon here apply as well to the marker variables of any other biological, behavioral, or social science. Gerontology is not less well served by its variables than are other areas of investigation. Indeed, it must be concluded that they are quite robust to have supported the enormous strides that have occurred in the study of aging in the past few decades. Obviously no biomarker can be flawless in all respects. Equally obviously, consideration of the gerometric issues identified here might improve their incisiveness and utility.

See also: Homeostasis, Homeodynamics and Aging; Models of Aging: Vertebrates.

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Marriage and Divorce

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Glossary

Divorce – The legal dissolution of a marriage before the death of either spouse.

Group Marriage – The marriage of two or more men to two or more women.

Marriage – A socially legitimate sexual union typically marked by a public announcement, commitment, and a written or verbal marriage contract.

Monogamy – The preferred form of marriage within Western cultures, in which there are only two spouses.

Polyandry – A marriage involving one wife having two or more husbands.

Polygamy – The practice of having more than one husband or wife.

Polygyny – A marriage type formed when one husband takes on two or more wives.

Serial Monogamy – Having more than one partner in sequence; is becoming more prevalent in cultures with high divorce and remarriage rates.

Introduction

Throughout human history, the institution of marriage has taken on a variety of shapes, functions, and meanings. Yet, marriage has almost always remained a sociosexual institution and a fundamental feature of family life and kinship structure. As such, it pertains to a specific social and sexual order with functions that are historically and culturally specific. In Western societies, it has traditionally been defined as a union between a man and woman, although same-sex marriages are legally recognized in some areas. In other parts of the world, polygamy, especially the marriage of a man to two or more wives, has been a more common form of marriage. Moreover, marriages are not always permanent – some end through the death of a spouse, while others end through divorce, separation, or annulment. Indeed, divorce, which is the legal dissolution of marriage, has become increasingly prevalent throughout many parts of the world. This emergent trend has significant implications for societies, family patterns, and relationships over the life course and in light of significant increases in life expectancy.

This article reviews patterns of marriage and divorce, beginning with an overview of marriage types and functions in selected Western and non-Western societies. Legal, social, and religious elements relevant to marriage and divorce are also reviewed. And wherever possible, attention is paid to

summarizing current knowledge on this subject from a gerontological perspective. This includes coverage of information that highlights dominant trends and implications for aging individuals and families in mid- and later life.

Defining Marriage, Religion, and Types of Marriage

Although precise definitions of marriage vary historically and cross-culturally, it can be defined as a state-sanctioned, socially legitimate union that occurs between two adults who cooperate sexually, economically, socially, and emotionally. Marriage is typically marked by a public ceremony, ritual, or announcement, such as a wedding, which provides a symbolic expression of the new social status of the bride and groom. Ceremonies range across and within cultures from very elaborate ones to the simpler act of acting married.

Religion often plays a role in these ceremonies and in most cultures. Generally, many religions provide extensive guidelines and teaching with respect to marriage. Christian churches tend to give blessing to a marriage, and the wedding ceremony usually includes some type of pledge by the community to support the couple's relationship. In Judaism, marriage is highly recommended, since it helps in the pursuit of spiritual perfection. It is viewed as the joining of two families, and it helps to perpetuate the religious and cultural heritage of the Jewish people. Hinduism conceives of marriage as a sacred duty that involves both social and religious obligations, while Buddhism tends to focus on how one can lead a happily married life. In the Eastern Orthodox church, marriage is viewed as an ordination and martyrdom.

Marriage is typically assumed with a written or verbal marriage contract, and this contract varies in the degree to which it can be broken. This contract also involves some idea of permanence, obligations to the family, and reciprocal rights. It is traditionally defined as a union between a man and a woman, although it has broadened in some jurisdictions to include same-sex marriage. Same-sex marriages are legally recognized in countries such as The Netherlands (2001), Spain (2005), Canada (2005), Belgium (2003), and the state of Massachusetts in the United States (2004). Some regions, such as Vermont, US, allow couples to apply for civil unions through which they receive virtually all of the legal benefits and protections given to married heterosexual couples.

There is wide variation in the form that marriage takes throughout the world. There are four types of marriage: monogamy, polyandry, polygyny, and group marriage. In Western cultures and countries such as China and Australia, monogamy, in which there are only two spouses, is the preferred form of marriage. In the twenty-first century, bigamy and sexual relations outside marriage are generally socially or legally frowned upon. However, since divorce and remarriage have become increasingly common, the practice of serial monogamy – or having more than one partner in sequence – has become more prevalent.

Polygamy, or plural marriage, is the practice of having more than one husband or wife. There are three forms of polygamy: polygyny, polyandry, and group marriage. Most societies permit polygyny, in which a man can have multiple wives, and it is generally a sign of wealth and power. The status of multiple wives varies from one society to another. This practice is found in many cultures throughout the world, such as the Middle East, Asia, and Africa, and in some fundamentalist Mormon groups in the United States (e.g., in rural areas among Utah's borders with Arizona and Colorado) and Canada (e.g., Bountiful, British Columbia). It is commonly sanctioned by religion, for example, in chapter 4 of the Qur'an, it is stated that in certain situations a man is allowed up to four wives. Although polygyny is preferred in many of the world's societies, preference does not necessarily translate into practice. This is because the number of men and women of marriageable age in most cultures does not create enough extra women to be available as second or third wives.

Polyandry is the practice of having two or more husbands. It is very uncommon, although considered to be the ideal marriage form in societies such as the Toda of India and the Marquesians of the Polynesian Islands, and among some Tibetans. Group marriage is relatively rare and involves the marriage of two or more men to two or more women. It tends to be found in societies in which plural marriage in the form of polygyny or polyandry already exists.

Free Choice and Arranged Marriage

In the West, the choice of a marriage partner is largely voluntary and depends upon the attachment between the partners. For example, in the United States, Canada, and many European countries, the most common reason for marrying is love, based upon a mutual emotional and/or physical attraction and the desire to form a lifelong commitment. In many parts of the world, such as many parts of Africa, Asia, and the Middle East, as well as within some cultural groups in Western societies, the choice of mates is deemed too important to be left to the individual and is often arranged.

Arranged marriages generally involve the role of an intermediary, through the involvement of two sets of parents or through negotiations with professional marriage brokers with prospective families. In most societies, the prospective bride and groom are consulted and they may have some power to reject the potential mate. Arranged marriages are practiced in order to preserve family resources, protect the economic well-being of the couple, and provide family continuity from generation to generation. Potential choices are usually limited to people of the same race and ethnic group and the same religion and class, and love and compatibility may be considered in order to provide the best possible match.

Rules, Regulations, Rights, and Obligations

In many parts of the world, marriage is a legal contract, with the state regulating economic and sexual exchanges between the couple. For example, in the United States, most states specify that individuals must be a certain age to marry, they must marry only people of the opposite sex, and they cannot marry someone with whom they hold certain kin relationships. Throughout history, societies have always placed restrictions on marriages. In particular, marriages to immediate relatives, such as between brothers and sisters, have generally been taboo and restricted (although ancient Egyptian royalty is a rare exception).

The institution of marriage unites people in emotional, social, legal, and economic ways that confer certain rights and obligations. These rights and obligations relate to children, holding property, sexual behavior, kinship ties, tribal membership, relationship inheritance, and intimacy. They sometimes establish the legal father of a child, give spouses sexual control over their partner's sexual services, establish a joint fund of property for the benefit of the children, and establish a relation between the families of the husband and wife.

Marriage Patterns and Family Relations

Marriage has traditionally been a prerequisite for starting a family. However, an increasing number of individuals (especially in Western cultures) are choosing to delay marriage or never marry, which means that the marriage rate is declining. More couples are also having children outside of legal marriage. Most individuals marry in young adulthood, although the average age of first marriage has increased steadily over the past century in most developed nations. Living together in cohabiting or common-law marriages is also on the rise and contributes to a decline in the marriage rate. This living arrangement is relatively common in countries such as Sweden and Canada and in other Western societies. Its roots can be found in a European tradition that marriage contracted between two adults was their own or their family's business and required neither civil nor religious sanction. In contemporary society, this practice is becoming very popular as a first conjugal union for young adults. For example, in the United Kingdom, about 60% of all marriages are preceded by unmarried cohabitation. Cohabitation is also becoming more common in mid- and later life, particularly following the end of a prior legal marriage. These relationships are different than legal unions since they are not contracted on the basis of a state's rules and regulations. As such, these unions are not always socially and legally recognized.

With rising divorce rates in many countries, individuals often remarry, although this is more prevalent at younger ages than in later life. Older adults, compared to younger adults, experience more negative social pressure about their decision to remarry. This negative social pressure sometimes originates from peers or adult children, the latter of whom may have concerns over such issues as inheritance. Adult children in Eastern cultures may also be afraid that they will be ridiculed for not taking their filial responsibility seriously, as observed in some Chinese families. In mid- and later life, men are more likely than women to remarry. The primary obstacles to remarriage for older women are the disproportionate number of women over age 65 and the cultural stigma against women marrying younger men, which is common to virtually all societies. The desire to remarry in later life may also be lower among divorced women than widowed women, which could be related to past negative experiences with marriage.

Remarriage introduces new complexities in aging family relations, since it is often described as an incomplete institution, without clear role boundaries and normative guidelines. For example, children may experience divided loyalties and difficulty coping with a step-parent family environment. Furthermore, among those who do remarry, a significant number are estimated to divorce again, creating complex stepfamily relationships among divorced adults in old age.

Marriage, Health, and Well-Being

Most research on marriage, health, and well-being has been conducted in the United States, although some cross-national research has been done. Generally, married people (with good marriages) report

higher life satisfaction and well-being and adjust to aging better than divorced, separated, and widowed individuals. Marriage is also linked to longer life expectancy, reduced stress, and better physical and mental health, especially for men. Older married adults also show lower rates of hospitalization. Generally, compared to those who are not married, married individuals eat healthier diets, engage in better self-care practices, and live more stable and scheduled lifestyles. Married individuals can also pool financial resources, which can buffer hardships linked to poorer health. Overall, a stable, long-term marriage provides a built-in support system, companionship, sexual intimacy, emotional stability, and a sense of security.

Most elderly men are married and live with a spouse, whereas the majority of elderly women do not. These gender differences lead to differential needs for support in the face of poor or failing health, since older men have a spouse to rely on. Older women often rely on their children, usually daughters, and more on public services. The absence of a spouse (and children) also increases the chance of being placed in a long-term care facility.

Termination of Marriage: Patterns in Divorce

Divorce, or the dissolution of a marriage, is the ending of marriage before the death of a spouse. It can be contrasted with separation and annulment, the latter of which is a declaration that a marriage is void due to certain circumstances (e.g., one spouse is already married). A divorce must be certified by a court of law in order to dissolve the legal act of marriage. The terms of the divorce are usually determined by the court and may consider prenuptial agreements, or terms that the spouses have agreed upon privately.

Divorce rates have risen dramatically over the past century in many developed countries of the world, especially in the United States, Canada, and many European countries, such as the Czech Republic, Belgium, Denmark, and the United Kingdom. Developing Latin American countries such as Cuba and Puerto Rico also have very high rates of divorce. Indeed, internationally, the United States and Cuba have among the highest divorce rates. For example, it is estimated that approximately half of all first marriages and 60% of remarriages in the United States end in divorce. Although divorce has also risen dramatically in many other societies, many countries continue to retain a relatively low divorce rate, such as Japan, Italy, and Vietnam (see **Table 1**). Divorce appears to be relatively rare (although increasing) in countries such as Turkey and Brazil and some parts of Africa, although data from civil registries are incomplete or unknown.

Table 1 Selected international crude divorce rates, 2003

Country	*Divorce rate*[a]
Australia	2.67
Austria	2.44
Belgium	3.03
Canada	2.24[b]
China	1.03
Cuba	3.02
Denmark	2.93
Dominican Republic	0.98
France	2.14
Iran	1.09
Israel	1.67[b]
Italy	0.73
Jamaica	0.61
Japan	2.22
Mexico	0.62
Netherlands	1.94
New Zealand	2.62
Seychelles, Africa	1.52
Singapore	0.83
Slovakia	1.99
Spain	0.75
Sweden	2.39
Uruguay	2.04[b]
United Kingdom	2.80
United States	3.80
Vietnam	0.50[b]

Sources: All data are from the United Nations, except for US data, which are drawn from the National Center for Health Statistics.

[a] Rates are the number of final divorce decrees granted under civil law per 1000 mid-year population.

[b] Only 2002 data were available.

In Western societies, divorce often occurs within the first 5 years of marriage, with youthful age of marriage being a consistent predictor of divorce. A substantial proportion of divorces also occurs after 5 to 15 years of marriage. Divorce rarely occurs once a couple has remained married for more than 20 years. In most cultures, the percentage of those who are divorced is higher for all age groups under 65 than for those over 65. Yet, the growing number of older adults who are divorced indicates the growing acceptance of divorce as an option among all age groups.

Legal, Sociocultural, and Religious Issues

From a historical perspective, divorce is a relatively recent phenomenon in virtually all societies. Many developed countries did not recognize divorce, and it was not until the middle of the twentieth century that many countries broadened divorce laws, which made it easier to obtain a divorce. Many of these societies

have moved toward no-fault divorce laws. For example, since 1970, beginning with California's Family Law Act, 48 US states have adopted no-fault divorce, while still providing for legal grounds divorce when applicable. This process eliminates fault-finding and the adversarial process such that the bases for settlement are equity, equality, and need rather than fault or gender.

Similar to marriage, different religions have different beliefs with regard to divorce. In the Roman Catholic church, for instance, divorce is traditionally not permitted because marriage is forged by God. Thus, many Catholic countries such as France and Italy have prohibited divorce since it is believed that couples should not and cannot be separated. Annulment is permitted in some special cases. Islam allows divorce, although it is discouraged and only the husband can decide to have no-fault divorce. In Judaism, divorce has always been accepted as a fact of life, and it is generally maintained that it is better for a couple to divorce than to remain together in a marriage that is in a state of constant strife.

Divorce, Aging Families, and Social Networks

The decision to end a marriage has significant implications for family members. To date, most research has assumed a deficit perspective – that is, that divorce has a negative effect on families. However, cross-cultural studies are beginning to show some positive outcomes, such as an increase in self-confidence and well-being and relief from a bad marriage. For women in particular, divorce can be positive if the marriage was abusive. Research also documents that adult children of divorce are more likely to divorce themselves compared to those raised with non-divorced parents. The quality and nature of the intergenerational relationship also change when parental divorce occurs later in children's lives, especially for young adult children. For these children, custody, visitation, and child support are no longer issues affecting the relationship. Yet parental divorce can lower the quality of the intergenerational relation and patterns of contact, especially for the father–child relationship. Generally, divorce can weaken kinship ties and obligations when it occurs later in life.

Studies also reveal the consequences of a child's divorce on the aging family system. One area that has received growing attention is the effect of divorce on grandparent–grandchild relations, since divorce can lead to a change in contact patterns. For some grandparents, the divorce can lead to a loss of contact, especially if their child becomes the non-custodial parent. In other situations, grandparents appear to have more contact, particularly when the adult child requires additional assistance and support with the raising of their children. A minority of grandparents become primary caregivers of their grandchildren when their divorced child is unable or unwilling to care for their children. This situation contributes to the formation of 'skip generation' households, since the middle generation is absent in the home.

Turning to the effect of divorce on couples, studies establish that divorce poses a crisis for some divorcing adults that results in a temporary decline in well-being, from which most individuals recuperate. However, for other individuals, divorce can set into motion a number of other stressful events, such as moving to another neighborhood, ongoing conflict with the former spouse, and economic hardship. However, adjustment to divorce largely depends upon characteristics of the individual (e.g., age, socioeconomic status, emotional stability, attachment to former spouse) and contextual factors (e.g., social support networks, custody status). Legal contexts can also shape adjustment processes, such as no-fault divorce laws, which can make divorce less emotionally painful to obtain.

Cultural factors are also integral to adjustment, since in some societies there may be a great deal of stigma associated with divorce. Opportunities (socially and economically) and legal contexts also vary from society to society. For example, in India and Japan, divorce is associated with more social stigma, and social opportunities are more limited. In India, divorced women are often isolated following divorce, due to the principle of *pativratya*, or the notion that a woman should devote herself completely to her husband's needs, even at the expense of her own. Divorced Indian women also find it challenging to find other single mothers with whom to develop social networks, while men retain both their household and the support of their extended families. Women are also more reluctant to seek friendships with Indian men since it might be misinterpreted. As a result, they are less likely to remarry than US women, which increases their social isolation. In Japan, divorced women traditionally experience discrimination in employment opportunities due to the impurity that divorce introduces into their family registry. The effect of this impurity can even spill over to their children. Generally, divorced individuals who reside in countries where divorce is less common are more stigmatized and fare worse socially and economically.

Overall, divorce tends to erode social support networks, especially ties to married friends. Retaining relationships with former in-laws is also fairly

unusual. However, friends and other family members often provide assistance to the divorced individual, particularly to older divorced women in Western societies. Older divorced men have relatively small social networks in comparison. This situation reflects their lesser involvement with their children and the tendency of men to rely on their spouses for emotional support. Also, since women are more likely to be kin keepers, divorced men lose this valuable resource, which is integral to the maintenance of social ties.

Divorce, Health, and Economic Well-Being for Aging Adults

Most research on divorce, health, and well-being has been conducted in Western societies, particularly the United States, although similar findings are observed across numerous societies and among various social and demographic groups. These studies have established that divorced individuals manifest more health problems and greater mortality than married or never-divorced individuals. A consistent finding in psychiatric epidemiology is that the highest rates of mental disorder are found among the divorced and separated, whereas the lowest rates are among the married and intermediate rates are among the single and widowed. Divorced individuals may also exhibit greater risk taking, such as elevated rates of drug and alcohol use and abuse. The recently divorced are at a particularly high risk for illness, possibly due to a weakened immune system as a result of the stress associated with divorce.

Divorce both in midlife and after midlife also influences a person's economic standing. Negative influences are generally more pronounced for older women, which may partly be a function of a more limited range of options. Many older women lack the requisite education, skills, and employment experiences that provide them with the ability to either reenter the labor force or advance their current positions. Although the financial responsibility to one's children decreases with age, many aging parents may continue to assist their young adult or adult children financially. When divorce occurs, the cost of maintaining two parental households may prohibit some of this assistance.

Summary

Marriage is a universal social institution that has historically and culturally unique forms and functions. Marriage and divorce laws regulate the marital agreement that two people make with each other and govern when a marriage can be dissolved. Social and religious contexts also shape these behaviors and experiences. The traditional view that marriage is a socially legitimate sexual union between a man and a woman is increasingly being questioned, such that legal definitions are expanding to include same-sex unions. The increasing popularity of cohabitation or common-law marriage also raises the question of this status as compared with legal marriage.

Marriage and divorce affect the lives of individuals and their families. Married individuals, in general, are found to experience a number of health and economic benefits over the life course, especially compared to divorced individuals. Divorce tends to erode social networks, particularly for older men, although older women often experience a decline in economic well-being. Older women may also experience stigma and isolation, although this may depend upon individual and cultural factors. Midlife and older women are also less likely to remarry relative to their male counterparts.

In the future, the institution of marriage is expected to remain highly valued and to persist in virtually all societies, despite the fact that marriage rates are declining and divorce among older age groups is rising. Undoubtedly, marriage will continue to transform and shape aging family life and social structures in significant ways. And given continued divorce, remarriage, and increases in life expectancy, there is the distinct possibility that we will witness more serial monogamy – that is, having more than one committed partnership in sequence – as well as marriages that will last for 50 years or more.

See also: Life Course; Religion and Spirituality.

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Medicare and Medicaid and Economic Policy of Health Care

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Glossary

Medicaid – The largest American program covering long-term care. Beneficiaries are defined as poor under state rules or qualified as low income recipients of a federal assistance program for the aged, blind, and permanently disabled.

Medicare – The largest American health insurance program for older persons, covering 35 million persons aged 65 and older.

Medigap – Supplemental coverage from private insurers to pay for expenses not paid by Medicare.

Introduction

The main focus of this article is Medicare. It examines its provisions and relationships to a cluster of programs for the health care of older Americans. In this cluster are included private insurance for some of the gaps in Medicare coverage (Medigap insurance), private insurance for long-term care (which Medicare does not cover directly), and Medicaid, federally supported state programs of assistance (charity) for medical and long-term care costs.

A major addition to Medicare is an outpatient drug benefit, conspicuously absent from the program for 40 years. The new program represents a departure from governmental administration seen in the traditional program. The new program, Part D, is an insurance market, with private insurers having great latitude in shaping the benefit, with options and sign-up procedures that confuse beneficiaries.

Medicare and Medicaid are mainstays of the American older population. Medicare is the largest American health insurance program for older persons; it covers virtually all 35 million persons aged 65 and older. In 1972, disabled workers on the Social Security disability rolls for at least 2 years were brought into Medicare. (In the same year, Medicare was extended to patients with end-stage renal disease.) Counting disabled workers, Medicare has 41 million beneficiaries.

Medicaid is the largest American program covering long-term care. Its beneficiaries are individuals defined as poor under state rules or qualified as low-income recipients of a federal assistance program for aged, blind, and permanently disabled persons (Supplemental Social Insurance, which uses income limits). Medicaid covers 53 million children and young and old adults, making it the largest American program of health insurance.

About 6 million individuals are 'dual eligibles' of both Medicare and Medicaid. They qualify for Medicare benefits because of their social insurance contributions and qualify for Medicaid benefits because they are poor. Counting the dual eligibles only once, Medicare and Medicaid together covered about 88 million persons in 2005.

Major aspects of the 2003 Medicare Prescription Drug, Improvement, and Modernization Act – particularly attempts to improve thrift and quality of care – are touched on in this article.

An Economy within an Economy

In 2005, Medicare and Medicaid spent over $620 billion of the $1.8 trillion spent on health care in the United States. If the programs funded a complete and

universal system instead of huge fragments, they probably would be hailed as one of the developed world's largest programs of national health insurance. Attempts to forge a national health insurance program in the United States have failed because of sharply divided opinion about the roles of government, private insurance, and market-based strategies.

Despite this enormous spending on health care, there were 42 million persons under age 65 in the United States in 2005 without health insurance. Many lost private coverage when they lost their jobs. Some became eligible for Medicaid because of poverty. The costs of their care plus the costs of care for the elderly poor in nursing homes and home-care programs strained state budgets and prompted calls for cutting Medicaid costs, particularly by going after beneficiaries who supposedly transferred assets in order to qualify as poor.

Despite its enormous spending, Medicare covered less than half of the health-care expenses of average beneficiaries in 2005. The largest item not covered by Medicare was long-term care. The Kaiser Commission on Medicaid and the Uninsured reported in 2006 that 1 million elderly persons were at high risk of needing care in a nursing home: they were age 85 or older, had no spouse, and needed help because of functional and cognitive impairments. With the annual cost of staying in a nursing home averaging $70 000, 62% of these individuals would exhaust their assets within 1 month of admission.

Research indicated that appreciable reduction of Medicaid spending was unlikely if targeted on higher penalties for transferring assets. The penalties were increased waiting periods before Medicaid payments to nursing homes would start. A patient who could not show the nursing home that he or she could pay during the penalty probably would not be admitted.

Taking a larger and larger bite out of the economy, inflation in health care and health insurance costs threatened the financial stability of young and old households as well as government budgets and corporation profits. According to a policy brief by the Brookings Institution, if historical trends persisted, the share of gross domestic product (GDP) going toward health care would climb from 15% to more than one-third by 2040. Such a proportion was considered politically and fiscally unacceptable. The author of the brief, Henry Aaron, noted that "with medical technology advancing at an ever-increasing rate, the potential for spending on procedures not worth their costs is growing. But there are few good ideas for reining in medical costs without hurting patients." (Henry J. Aaron (2005) *Health Care Rationing: What it Means*. Washington, DC: Brookings Institution. Policy brief #147 [abstract]).

Some American businesses complained that their health insurance costs undercut their ability to compete well in international markets; foreign businesses were said to bear lighter burdens under national health insurance. The blame for higher US costs is sometimes laid unfairly at the door of the older American population and its financial and health-care supports. What should be noted is that developed countries with larger proportions of elders in their populations had lower health-care costs as a percentage of GNP than the United States.

Both Medicare and Medicaid do have problems controlling costs. They are embedded in an extravagant health-care system. Both have deficiencies in range of benefits and quality of care from a geriatrics viewpoint, where the preference would be for a seamless system of preventive, acute, long-term care and social services. The health system that exists and changes slowly is marked by waste, inadequate and uneven population coverage, and a heavy bias toward acute care.

History and Philosophy

Medicare payment patterns – ranging from public or social insurance to the use of market and private insurance mechanisms – reflect political philosophies in vogue at various times before and since Medicare's enactment in 1965. The emphasis at the start was primarily on social insurance concepts and dedicated payroll taxes formulated by the Democratic Party and brought to fruition in 1965 when Lyndon B. Johnson was president. In 2003, during the administration of George W. Bush, a Republican, Medicare introduced an outpatient drug benefit grounded on market strategies rather than social insurance. The 2003 act intensified Medicare's promotion of managed care systems sponsored by private insurers. Mirroring the President's desire to privatize Social Security pensions, the reigning belief in Medicare administration was that program economies could be effected more or better by markets than by government administration.

Medicare and Medicaid are rooted in the Social Security Amendments of 1965. Title XVIII of the act was Medicare for retired workers, and Title XIX was Medicaid for the poor. Medicare emerged in the law in a form that differed from its original focus on hospital benefits backed by compulsory payroll taxes, a pattern opposed by organized medicine. In search of a broad consensus, the House Ways and Means Committee under its Democratic chairman adapted a Republican proposal for subsidized voluntary insurance acceptable to organized medicine,

Medicare Part B. This plan focused on physician services financed through beneficiary payments (premiums, deductibles, and coinsurance) and federal general revenues rather than a dedicated payroll tax allied with Social Security. Contrary to the desire of organized labor to minimize the use of private insurers, the final legislation placed day-to-day administration in the hands of insurance companies familiar to hospitals and physicians, with overall control by the Social Security Administration.

Medicaid was administered by another unit of the Department of Health, Education, and Welfare (HEW). Later, both programs were lodged in the Centers for Medicare and Medicaid Services (CMS) of the Department of Health and Human Services (HHS), successor to HEW. Placing both programs in one administrative agency seemed to make sense inasmuch as the programs dealt with many of the same providers of service and dealt also with an overlapping population of beneficiaries. For poor Medicare beneficiaries on Medicaid, the latter paid for Medicare deductibles, premiums, and coinsurance. Actually, Medicaid offered older persons a broader slate of health benefits than Medicare; for example, Medicaid covered long-term care, outpatient drugs, routine dental care, and preventive health care, all of which were not included in the original Medicare program.

An erroneous belief that Medicare included long-term care persisted for many years. What misled many persons was that Medicare made use – but only limited use – of nursing homes and home-care programs identified with long-term care. The Medicare law spoke of extended care, a benefit allowed for convalescent and rehabilitative services in a nursing home or home-care program after a 3-day hospitalization for an acute illness. As long as a patient needed treatment for the acute problem, custodial care in the nature of assistance in dressing, bathing, and other activities of daily living was covered by Medicare.

No geriatrician was at the decision-makers' table when Medicare was designed. The plan largely represented reliance on models from private insurance, which focused on medically necessary costs of acute care. Medicare was primarily an insurance program rather than a health program. Over the years, Medicare became more oriented toward preventive health care. When Medicare began, many beneficiaries expected the program to cover long-term care, but it was not in the law. Decades after Medicare began, insurance agents said they found many older persons harboring the belief that Medicare had a long-term care benefit. A reason for this omission was lack of insurance company experience on which to rely for estimating the costs of long-term care benefits. A common belief in Congress was that a long-term care benefit would stimulate demands for services that Medicare could not afford or control.

Medicare in Outline

The major elements of Medicare are Part A (hospital insurance), Part B (insurance for doctor, clinical laboratory, and outpatient clinical services), Part C (federal payments to capitated managed care systems), and Part D (outpatient prescribed drugs furnished through private insurers and managed-care systems). Parts A, B, and C are noted briefly here to give a context for discussing Part D. More detail on A, B, and C follows in another section.

Part A is supported by federal payroll taxes on employers and employees, Part B by beneficiary payments (25% of program) and federal general revenues (75%). Under Part A, the Medicare administration sets payment rates across the nation for hospital services sorted into diagnosis-related groups. Under Part B, Medicare pays chiefly for fee-for-service medicine according to resource-based relative value scales with geographical and other adjustments.

In Part C, the Medicare administration and managed-care systems negotiate an annual rate per beneficiary (capitation). The systems are at risk for costs beyond the capitation income. Funds for hospital and physician services are drawn from Part A and Part B.

Medicare Part D

Part D represents a private insurance market supported by beneficiary and federal payments, with minimum government oversight. As Part D began in 2006, 260 private insurers sponsored drug plans meeting minimum federal requirements for a novel drugs-only insurance approach. The plans were free to set premiums and deductibles, being mindful of competition by premium price and formulary, the list of drugs that the insurer chose to cover, provided the list had at least one drug in specified categories.

A controversial section of the 2003 Medicare Prescription Drug, Improvement, and Modernization Act prohibited Medicare from bargaining on price with drug makers. It authorized insurers to do the bargaining. (Meanwhile, the government bargained on prices for the Department of Veterans Affairs and secured large discounts.) The insurers were at risk for losses experienced by their programs.

About 29 million of the 41 million Medicare beneficiaries were expected to enroll in Part D in its first

year, 2006. Of 14.2 million persons eligible for low-income subsidies, 8.7 million were expected to apply and receive them. A study for the Kaiser Family Foundation estimated that 19 million enrollees would probably spend less on prescribed drugs, 7 million would spend more, and 3 million would spend about the same in out-of-pocket costs as they did before Part D. Because of premium subsidies, beneficiaries would pay on average about 25% of total Part D costs. An average drop of 83% in out-of-pocket costs was forecast for 8.7 million low-income beneficiaries. A decline of 37% (to $792 from $1257) was forecast for average Part D enrollees in 2006.

Part D was open to beneficiaries participating in traditional Medicare; participation was optional. Enrollment was not easy: applicants had the job of sizing up the market of plans available in their locales, sometimes well over a dozen. They had to identify those plans, review their premiums, and check their formularies to see if the generic or branded drugs they needed were listed at the needed dosage. Plans were at liberty to amend the formulary at any time, provided they gave 60-day notice during which the beneficiary could switch to another plan. In the initial year, one switch was allowed after the May sign up deadline. Ordinarily, the Part D participants had a once-a-year period to switch plans.

When satisfied with the details of a particular plan, the applicant had to sign up with the plan or sign up with Medicare. Dual eligibles were assigned to a plan by the state Medicaid agency. Participants in managed-care plans that already had drug benefits did not have to change; they might even see their benefits improve under Part D reimbursement.

Medigap plans could participate in Part D if they established a separate plan for drug coverage. Medicare beneficiaries in employer-sponsored retiree programs that included drug coverage deemed equal to Part D could stay in that program. If coverage was not equal to Part D, they could stay, but had to know that a late-enrollment penalty, a premium surcharge, would be applied in the future if they opted for Part D. The act offered subsidies to employers to maintain drug coverage in their retiree plans rather than discontinue the coverage and see retirees enroll themselves into Part D.

Part D provided subsidies to employers for maintaining their retiree drug coverage if found equal to the Medicare coverage. The subsidies were justified as necessary to prevent employers from closing down their programs and leaving drug payments entirely to Medicare. A survey of 300 of the largest US private employers found that 80% would accept government subsidies for continuing to offer retiree drug coverage in 2006. While most of these companies said they were likely to accept the subsidies in 2007, only half said they would do so in 2010, and 22% said they probably would not do so. The remaining 28% did not know.

The survey also found that many subsidy-taking firms had policies concerning retirees who enrolled in a Part D drug plan. Some 29% of these firms said that retirees taking such a plan would lose employer-sponsored medical and drug coverage, 31% said such retirees would lose only the drug coverage and retain other benefits, and 41% said retirees taking the Part D coverage would not be able to retain other benefits in the future. Firms that would continue to offer benefits and accept the subsidy in 2006 would save, on average, $626 per retiree. Firms that would supplement Part D and retain other benefits would save $826 per retiree.

Part D as a whole was criticized for give away to insurers and drug makers. When the Bush administration brought the legislation to Congress, the estimated 10-year cost was about $500 billion. A higher estimate was withheld from Congress before enactment. Some Republican members of Congress were upset by costs of the proposal endorsed by President Bush, while Democrats were upset by a precedent for privatizing more of Medicare and by the complexity of the program. The House of Representatives approved Part D by a narrow majority after the Republican leadership extended the time for voting to 3 hours (versus the customary 15 minutes). The extra time was used to round up and pressure members to back the President.

The model laid out in the legislation called for a maximum $250 annual deductible. After it was met, the plan covered 75% of total drug expenses, up to $2250. The enrollee paid 25%, or $500 ($2250 minus $250 = $2000 × 25% = $500; the remaining $1500 was paid by Medicare). After $2250, the program paid nothing until the total spent by the enrollee and Medicare reached $5100. Beyond this 'catastrophic' level, Medicare paid 95% of drug expenses and the enrollee 5%.

Medicare Parts A, B, and C

Most of Medicare spending is through Part A, or hospital insurance. Part A is funded primarily by a dedicated payroll tax of 1.45% paid by employers and 1.45% paid by employees on earnings up to a specified ceiling ($90 000 in 2005). Over the long run, some critics contend, this rate will not be high enough to cover the Baby Boom retirees and the expected rise in health costs at a pace faster than the growth of the economy.

Part A eligibility typically is established automatically at age 65 for persons with a specified record of payroll contributions made in parallel with Social Security (pension) contributions. Older persons lacking full Social Security status (because they had insufficient payroll credits) may buy into Part A.

In addition to hospitalization, Part A pays for posthospital care in a skilled nursing home or home-care program (for rehabilitation and convalescence), and for hospice care (for patients near death who require treatment for comfort and pain relief). Admission to a Medicare-participating hospital triggers a Part A deductible set by national formula ($912 in 2005). Only one deductible is charged for 60 days, even if there is a readmission for the same diagnosis after a brief interval at home or in the community. After 60 days of hospitalization, the patient incurred in 2005 a per diem charge of $228 until day 90, and thereafter until day 150 a per diem of $465.

The designers of Medicare were advised by private insurers to adopt this approach as a deterrent to long and unnecessary hospitalizations. Almost all Medicare hospitalizations nowadays are for less than 30 days. More in keeping with the finances of older people would have been a 30-day benefit, budget neutral, with no deductible. Part A provides for a limited amount of care (20 days) in a skilled nursing home at no cost to the beneficiary after a hospital stay of 3 days. From day 20 to day 100, the per diem charge in 2005 was $114. Home care was at no cost to the patient as long as medically needed and provided by a Medicare-approved agency.

Parts A and B constitute traditional Medicare. Hospitals are paid on the basis of costs generated in diagnosis-related groups of services (DRGs). Physicians are paid mainly by fee-for-service using resource-based relative value scales (RBRVSs), derived mainly from studies of time with patients for interviews and for conducting procedures.

In addition to physician services, Medicare Part B provides for clinical laboratory services, outpatient clinical services, and medically necessary equipment, such as wheelchairs. Part B is technically a voluntary program, but virtually all Part A beneficiaries choose it, pay a monthly premium, and meet an annual deductible before being reimbursed. In 2006, the Part B premium was $88.50 per month and the deductible was $124 per year. The law fixes Part B financing as 75% from federal general revenues and 25% from patient payments, such as premiums and coinsurance.

The model for physician payment, in brief: a Medicare-participating physician agrees to accept a Medicare approved charge as the full charge for a service. The approved charge represents a Medicare fee schedule using the RBRVS. Based on empirical research into what physicians actually do, this methodology established a Medicare fee schedule considered to be more fair than payment under the loose concept of 'reasonable and customary fees.' The method was said to improve payment for primary care services and usefulness in controlling costs.

If the patient's Part B deductible has been met ($124), Medicare sends 80% of the approved charge directly to the physician. The patient, or the patient's private Medigap insurance (see below), pays the remaining 20%. If the physician does not accept this method (called assignment), the physician sends the patient a bill. A physician may not legally collect more than the approved charge plus 15% from the patient. Medicare sends the patient a check for 80% of the approved charge. The patient pays the 20% plus the 15%. Most physicians take assignment because payment is quicker and more reliable. For patients, there is less paperwork and postage.

Medicare Part C covers managed-care systems, which are private insurance plans that provide hospital, physician, and other services under central management for an annual sum. Beneficiaries who join a system give up the option they have under traditional Medicare to obtain service from any participating hospital, physician, or other unit. The beneficiaries are limited to the system's providers, unless the plan has an option allowing provider choice outside the plan; the beneficiary pays extra for it.

An annual contract is negotiated between Medicare and a managed-care system, which can be an HMO (health maintenance organization) or a PPO (preferred provider organization). This contract limits the government's spending. The managed-care system takes the financial risk for costs beyond the payment negotiated with the CMS. The beneficiary continues to pay the monthly Part B premium. A system may charge an additional premium for benefits beyond those of Part A and Part B.

Medicare Part C aims to attract beneficiaries from traditional fee-for-service Medicare by offering them improved controls on costs and quality of service. Private insurance companies sponsor managed-care benefits, called Medicare Advantage. Previously, the benefits were called Medicare + Choice. Medicare + Choice began with an assumption that the plans, because of their cost controls, would readily average 5% less than per-beneficiary costs under traditional Medicare. Savings above 5% could be applied to additional benefits (such as dental care, eyeglasses, or prescribed drugs) or reduction in the managed-care premium. In 2004, significant numbers of beneficiaries returned to traditional

Medicare because of dissatisfaction with administrative restraints on service use. Meanwhile, some plans proved more costly than traditional Medicare and dropped out of Part C. In Congress, higher Medicare payments were authorized to keep plans going in Medicare. Calculations by the Commonwealth Fund indicated that the plans cost $2.72 billion more than traditional Medicare.

Medigap

Some 22% of Medicare beneficiaries bought supplemental coverage from private insurers (Medigap policies) to pay for expenses not paid by Medicare. One-third of Medicare beneficiaries had gap coverage from their former employers, and 14% had gap coverage from Medicaid because they were dual eligibles. Coordinated with Medicare, Medigap paid what was left of the approved charge after Medicare paid its 80% and the Medicare deductible had been met. Medigap policies paid the residual amount of an approved charge, provided that the separate Medigap deductible also had been met. To help beneficiaries evaluate Medigap policies, the federal government established 10 categories of benefit packages with price and other characteristics.

Private Long-Term Care Insurance

Of the $180 billion the nation spent on long-term care in 2002, 10% was paid by private insurance, 17% by Medicare (coincident to treatment for an acute condition), 21% out of pocket by recipients or families, and 47% by Medicaid. An estimate for the cost of long-term care in 2005 was $200 billion. The cost of unpaid or informal care by family members and friends was estimated at another $100 billion.

Private long-term care insurance, available from 100 insurance companies, generally offered a choice of premiums for a mix of care at home, in assisted living facilities, and in nursing homes, depending on selection of (1) waiting periods of 60 or 90 days before benefit payments start; (2) per diem amounts or overall spending caps; (3) inflation protections, such as periodic 5% rises in per diem amounts or caps; and (4) length of coverage, such as 3, 5, or more years. Age of the would-be insured person and sickness risk also were factored into premiums. A number of policies did not exclude coverage for Alzheimer patients.

Many middle-class individuals at or nearing retirement age were deterred from buying long-term care insurance because of the expense, which was relatively high for their retirement incomes. Insurers generally encouraged purchase of long-term care policies when people were in their 40s or early 50s, when premiums are relatively low, and when there is time to build reserves. There appeared to be a persistent public reluctance to buy the policies.

To encourage purchase of long-term-care insurance, the cost of policies meeting federal standards may be deducted in part from income taxes. In a few states, after a private policy meeting special requirements has paid for at least a year of long-term care in a nursing home, a policyholder may be eligible for Medicaid coverage with no risk to assets. However, income limits would apply and an examination of income receipts would be necessary for Medicaid.

Insurers may raise premiums for a class of policyholders but not for specific policyholders. If the insurer by design or happenstance accumulated more heavy-expense policyholders than justified by premium income, the insurer could go out of business, merge with another company, or raise premiums for a policyholder class. The regulation of insurers was largely in the hands of state insurance departments, some considered more friendly to insurers than to consumers.

Medicaid

All 50 states, the District of Columbia, and other jurisdictions had Medicaid plans meeting federal requirements on scope of benefits and administration. Fifty to eighty percent of the costs of these programs for the poor – children, expectant mothers, and others in addition to older persons, on whom this article focuses – were financed by the federal government. Poorer states received higher grants than richer states. All Medicaid programs had to cover hospital, physician, clinical laboratory, nursing home, dental, mental health, and outpatient clinic services. Home-care service was a benefit the state could adopt with federal approval.

The qualification of individuals to receive benefits was contingent on proof of poverty (a means test by the state, taking account of income and assets). While states had considerable latitude in designing programs, they had to cover aged, blind, or permanently disabled persons who received Supplemental Security Insurance (SSI), a federal program with an income test. For example, elderly and disabled beneficiaries with income below 74% of the federal poverty level ($6768 a year in 2005) had to be covered.

Nursing home residents with incomes above SSI levels but below $1692 a month may be covered. States can expand their programs with federal consent. If granted a waiver, a state program might cover individuals at risk of needing nursing facility care although still living at home.

A state may choose to cover medically needy persons for mandatory benefits, such as hospital,

nursing home, and physician services. A medically needy individual is a person who has an income that exceeds state limits but, net of health-care expenses, falls below the limits. A state may also choose to cover the medically needy for home and community-based services.

See also: Economics: Society; Health Care and Services; Social Security.

Further Reading

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Relevant Websites

http://www.medicare.gov – Centers for Medicare and Medicaid Services. This address opens to the official explanation of Medicare benefits for beneficiaries, "Medicare and You." It is updated at least yearly. For technical features of Medicare and Medicaid, the address is http://www.cms.hhs.gov/. The centers (CMS) is the federal agency supervising Medicare and Medicaid programs. The website covers the two programs and regulations, guidance, research, statistics, and systems, outreach, and education.

http://www.cmwf.org – Commonwealth Fund. The fund, a nonpartisan, research, and education organization, tracks trends in health coverage, access, and quality, and general policy/practice issues in the United States and internationally. All information is available free of charge. Raw data are available to researchers 1 year post-release. Major topics on the website include Medicare, Medicaid, care of the elderly, health system performance, long-term care, quality of care, and international health policy.

http://www.kff.org – Kaiser Family Foundation. This nonpartisan organization presents reports, briefs, and fact sheets with current information on many aspects of Medicare, Medicaid, health insurance and the uninsured, health policy, retiree health benefits, and state Medicaid health benefits and fact sheets.

http://www.aoa.gov – US Administration on Aging (AoA). This agency looks at population change in many dimensions, with attention to systems changes needed to prepare for aging and long-term care needs of the Baby Boomers.

Memory

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Glossary

Episodic Memory – Storage and retrieval from long-term memory based on contextual information about original learning experience (internal diary).

Implicit Memory – Indirect effects of memory without conscious awareness.

Prospective Memory – Remembering to do something in the future (intention to remember).

Semantic Memory – Storage and retrieval from long-term memory based on the conceptual nature of to-be-remembered information (internal encyclopedia).

Short-Term Memory – Memory for recent events that have been maintained in conscious awareness prior to recall.

Working Memory – Type of short-term memory that involves maintenance of information at the same time one is engaged in an information-processing task.

Introduction

It is clear that memory changes with age. Serious memory decline is associated with many of the diseases of old age (e.g., Alzheimer's disease), but memory change is also characteristic of normal, healthy aging. There are hundreds of research studies showing reliable age differences on a variety of different memory tasks. The age differences are seen with both cross-sectional and longitudinal research designs. It is also true that not all memory changes with age in the same way. Whereas some memory tasks show large adult age differences (e.g., working memory, episodic memory), other tasks show little or no effects of age (e.g., semantic memory, implicit memory). The explanation for these differential effects of age on different memory tasks depends on how one conceptualizes memory. Some theories suggest that age differences will be large when the task involves deliberate cognitive processing or the use of cognitive resources. The more cognitive resources needed to adequately remember, the larger the age differences. Other theories suggest that age effects are limited to specific memory processes or memory systems. It also has been suggested that memory differences between age groups are not memory effects at all, but rather reflect other confounding variables, such as health, motivation, or differential experience effects.

Theoretical Perspectives to Aging and Memory

Memory Stage Theory

Memory stage theory separates memory into the sequential components of remembering. As diagrammed in **Figure 1A**, information first has to be experienced at time 1 (i.e., encoding), then it has to be maintained over a retention interval from time 2 to time *n* (i.e., storage), and finally it has to be reproduced when memory is tested at time *n* (i.e., retrieval). Early researchers believed that adult age differences in memory were located primarily at retrieval, the final of the three stages of memory. For example, in the laboratory it was demonstrated that age differences in free recall of a word list (with instructions such as, 'Write down all the words you can remember having seen on the list earlier') were eliminated when recognition memory was used (with instructions such as, 'Pick out the words from this list that you saw earlier'). Because the use of a recognition memory task is assumed to reduce the retrieval requirement of the memory task, it was then inferred that the locus of the age effect must be retrieval. When retrieval requirements are large, such as in free recall, age differences are large; when retrieval requirements are minimal, such as with recognition memory, age differences are small or even non-existent. Such findings were prevalent in the 1960s and early 1970s. More recent research, however, has clearly demonstrated reliable age differences in recognition memory, and stage theory lost its appeal because of the methodological difficulties in isolating one memory stage from another in different age groups. In order to isolate retrieval, for example, everything must be held constant up until the time retrieval is tested. This is difficult to accomplish in aging research, however, because adults of different ages may process information differently at one of the earlier stages, thus violating the requirement that all be held constant until retrieval.

One interesting phenomenon that is associated with the retrieval stage of memory is the 'tip-of-the-tongue' state. There are many instances in everyday life when we cannot remember something even though we know that we know it. One way that this tip-of-the-tongue state has been simulated in the laboratory is by having subjects read definitions of words and then attempt to remember the word that goes with each definition. A tip-of-the-tongue state occurs when retrieval is blocked and the subject cannot think of the word that goes with the definition, even though he or she is absolutely confident that the word is known. In fact, subjects can often remember specific partial information about the words (e.g., number of syllables, the beginning letter of the word) even though they cannot access the word itself. Research shows that older adults experience more tip-of-the-tongue states than younger adults, are slower at resolving the retrieval blocks, and often have less access to partial information. However, when given sufficient time to resolve the tip-of-the-tongue block, older adults eventually may come up with the words, just like younger adults. The same result occurs with name-finding and picture-naming tasks.

For reasons not directly related to memory stage theory, memory research in the 1970s and early 1980s focused heavily on the encoding stage of memory. This focus on encoding was due to the development of a conceptual view of memory, the 'levels of processing' framework, that proposed that the ability to remember was determined by the extent of semantic processing engaged in during the encoding of the to-be-remembered information. For this reason, most cognitive aging researchers during this period focused on encoding processes and aging. That emphasis may have been well placed for several reasons. First, the memory performance of older adults, relative to

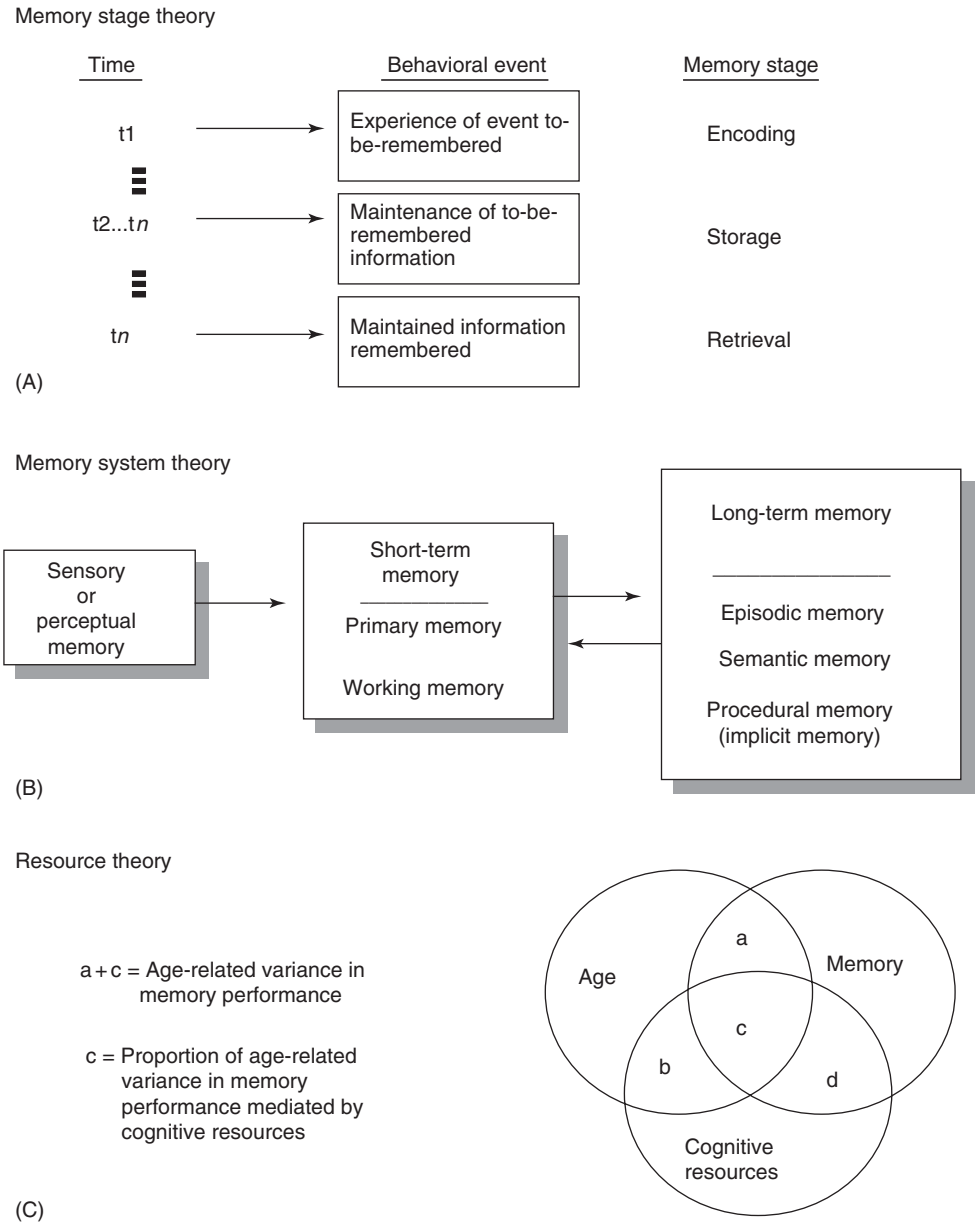

Figure 1 Three conceptualizations of memory useful in describing age differences in memory: (A) memory stage theory; (B) memory system theory; and (C) resource theory.

younger adults, is detrimentally affected by performing a divided attention task during the encoding stage of a memory task, but not if the divided attention task occurs at retrieval. Furthermore, data from neuroimaging studies with older adults suggested that age-related memory effects may be greater at encoding than at retrieval. By using functional neuroimaging, researchers are able to determine which areas of the brain are active while subjects perform different cognitive tasks. In several laboratories, it has shown more activation in the left hemisphere during the encoding stage of a memory task and greater activation in the right hemisphere during the retrieval stage, a lateralization of encoding and retrieval in different regions of the brain. When neuroimaging studies are done with subjects of different ages, the activation in the left prefrontal lobe seen in young adults during encoding is greatly attenuated in older adults. However, few age differences are detected in the level of activation in the right hemisphere when subjects are engaged in retrieving information from memory. This neurological evidence suggests that memory problems with aging may be more involved with encoding than with retrieval.

Memory System Theory

Another conceptualization of memory that has both behavioral and neurological support considers memory not to be a unitary construct, but rather a collection of different component systems. As can be seen in **Figure 1B**, memory is broken down into sensory memory, short-term memory, and long-term memory. Short-term memory is further divided into primary memory and working memory, and long-term memory is divided into episodic, semantic, and procedural memory. These systems differ in the nature of memory representations and how these representations are maintained and retrieved. They also differ considerably in the effects of aging.

Sensory-Perceptual Memory After an event is experienced, it is first represented briefly in the sensory-perceptual system. Here the information is represented as it is processed and analyzed by the perceptual systems. There has been very little work on this type of memory and aging, but some research does suggest that older adults are less efficient in this early type of processing, especially in the visual system. It should be pointed out, however, that differences in sensory-perceptual processing would be an unlikely candidate for an explanatory construct for memory differences found in later systems because later memory differences are not consistent, but vary according to what system is examined. Adequate perceptual processing of the to-be-remembered stimulus would seem to be a requirement for all types of long-term memory, and the fact that some long-term memory systems are minimally affected by aging while others show large effects would not support an explanation that relied solely on faulty perceptual processing at the very early stage of processing the information.

Short-Term Memory Short-term memory is conscious awareness. It consists of information that is currently in mind, a combination of incoming information being attended to from the sensory-perceptual system and information being retrieved from long-term memory to interpret and process the incoming information. For this reason, short-term memory is thought of as a complex information-processing system that involves a combination of storage (i.e., keeping things in mind) and processing.

The storage component, or how many things you can keep in mind at one time, is often called 'primary memory.' The digit span test found on most intelligence tests is a measure of primary memory. In this test, different strings of single digits are called out, and the subject has to repeat the digit strings. If the subject is correct, then an additional digit is added to the next string. Digit span is measured as the longest string of digits a person can repeat without making an error. When primary memory is tested by digit span tests with subjects of different ages, no reliable age differences are found.

Age differences are found, however, on measures of short-term memory that take into account both processing and storage. 'Working memory,' unlike primary memory, requires subjects to keep information in mind while engaging in another processing task at the same time. One commonly used working memory task is called reading span. Subjects read a series of short sentences (e.g., 'The boy ran with the dog') and answer questions about the sentence (e.g., 'Who ran?'). At the same time, subjects have to remember the last word in each of the sentences (e.g., 'dog') and report the words when told to do so. The number of sentences presented prior to recall of the words ranges from two to seven, and working memory capacity is the longest list of sentences for which subjects can correctly report the words. Because working memory tasks require simultaneous storage and processing, it is a better simulation of the everyday information processing required to understand language, solve problems, or make decisions. Other working memory tasks have been developed that involve different kinds of information processing such as arithmetical calculations (computational span) or spatial manipulations (spatial working memory). With all of these tasks, large, reliable age differences are found. Therefore, while the more passive primary memory tasks, such as simple digit span, do not show age differences, differences are found with working memory measures. As is discussed later, working memory capacity is considered by many researchers to be a fundamental mechanism for memory processing. Because age differences exist in working memory, and because working memory is assumed to be a fundamental requirement of processing efficiently at encoding and retrieval, this measure has been considered an important factor in determining the complex age differences seen in long-term memory.

Long-Term Memory Long-term memories are not kept in conscious awareness like short-term memories, but instead have to be retrieved when needed. Long-term memory is usually divided into episodic memory, semantic memory, and procedural memory.

Episodic memory Episodic memories are those recollections that are actively retrieved from personal experiences. In other words, the contextual information about when and how an event was originally

experienced is used to guide retrieval. 'Where did I leave my keys?' 'When did I last see Mary?' What was I supposed to get at the grocery store?' Each of these questions involves remembering by reconstructing the context of the original experience.

Episodic memory has been studied extensively by cognitive aging researchers. Typically, a list of words, or some other to-be-remembered information is presented to subjects, and then later, after a retention interval, memory is tested. Because the words were already known to the subjects, the memory task is to remember the words in the particular context of the presented list. While the magnitude of age differences varies considerably among different memory tasks using different materials, older adults tend to have greater problems with episodic remembering than do younger adults. The variable that seems important in determining the magnitude of age differences is the degree to which the memory task involves deliberate processing by the subject. At both encoding and retrieval, the more intentional processing required to perform the task, the larger the age differences that will be found with that task.

For example, if the to-be-remembered materials are complex pictorial scenes such as those that might be found on picture postcards, old adults remember them as well on a later memory test as younger adults. Because the pictorial images are rich in both semantic and visual context, little deliberate processing is necessary to encode the materials. This is called 'environmental support,' because the task and materials themselves provide the cues necessary for optimal performance. When the pictures are deleted of their rich content, however, either by taking out perceptual detail or by rearranging the components of the pictures to reduce meaningfulness, age differences are produced. Age differences can be increased by reducing environmental support and thereby increasing the requirement for deliberate processing on the part of the subject to adequately encode the information.

The same phenomenon is found for retrieval from episodic memory. The way in which the retrieval task is structured can influence the magnitude of age differences on the task. Earlier, it was mentioned that age differences in free recall are larger than age differences in recognition memory. In free recall, after seeing a list of common words, subjects are asked to recall as many of the words as possible. Other than the instruction to remember the words, no other cues are provided to the subjects, and age differences are typically very large on these free recall tasks. If recognition is used, however, age differences are considerably reduced. Instead of trying to free recall the items, subjects in a recognition task only have to pick out the words they saw earlier on a longer list of words presented at test. Compared to free recall, a recognition task provides the very best retrieval cues, the words themselves, and little deliberate retrieval is required to perform the task. Thus, age differences are greatly reduced because of the environmental support provided by the recognition procedure.

Because episodic memory is so dependent on contextual information, one of the reasons for older adults' poorer performance in these tasks is probably their inability to encode contextual information easily. Older adults, for example, do not do as well as younger adults in identifying the way in which information was presented to them. They do worse when asked to remember whether a word was presented in upper or lower case, presented auditorially or visually, spoken by a male or a female voice, in one color versus another, or in the upper part of a computer screen or the lower part. These tasks (often called source memory tasks) require subjects to remember contextual detail. Because older adults encode less contextual detail, they do not do as well on these tasks. In fact, because older adults encode less context, they are even less able to distinguish between events actually experienced from those just imagined, a process called 'reality monitoring.' In a typical reality monitoring experiment, subjects either read words at encoding or generate words in response to some cue. Older subjects have greater problems in determining whether remembered events were the ones read or the ones imagined in response to the cue. Older adults also have problems in being able to come up with new words when given a cue (e.g., 'Give me the name of a fruit not mentioned before'). Older adults are more likely to generate words generated earlier in the task (inadvertent plagiarism).

Because of the dependence of episodic remembering on context, an important principle in determining the level of performance is the 'encoding specificity' principle. The encoding specificity principle states that the optimal condition for episodic remembering is when the contextual situation at retrieval matches the contextual situation that was experienced during the original encoding. Because older adults encode less contextual detail, they should be less influenced by the encoding specificity principle. Some studies, however, find that young and old subjects are affected in the same way by changing the contextual situation at retrieval, such as using cues at retrieval different than those used at encoding. Other studies, however, find that the older subjects are less affected by contextual change from encoding to retrieval. The distinguishing feature of

these studies seems to be the extent to which the context at encoding was integrated with the to-be-remembered information. Studies showing equal encoding specificity effects often involve cues and memory targets that are already integrated and do not require deliberate processing to relate them together. The studies showing less encoding specificity in older adults, on the other hand, involve situations in which integration of the target with the context requires deliberate processing by the subjects. This supports the view stated earlier that episodic memory deficits in older adults are increased by increases in the processing requirements of the task.

Older adults also have more memory illusions. They are more likely than young adults to produce false memories, producing a word that was not presented on an earlier list because it is related to words presented earlier. For example, when words related to the word 'sleep' are presented (e.g., nap, bed, snore), they are more likely to falsely recall the word sleep when later asked to recall the words on the list.

One interesting type of episodic memory, 'prospective memory,' involves remembering to do something in the future rather than remembering something from the past. 'Don't forget to take your medicine at noon today.' 'When you see Bill, tell him I called.' 'Will you pick up the kids after work today?' All of these memory tasks produce an intention to remember in the future, or remembering to remember. Age differences are typically found with simulations of prospective memory tasks performed in the laboratory (e.g., press a key when the face has a beard, ask for a red pen when signing your name, or phone the laboratory at a certain date). With simple laboratory tasks, however, such as pressing a key when a certain word is presented, age differences in prospective memory are not found. Again, the determinant of whether age differences are found seems to be the degree of deliberate recollection required to perform the task.

In one study, age differences were found when subjects were asked to press a computer key every 10 min while performing another computer cognitive task (time-based prospective memory), but were not found when they were asked to press the key when a certain cue word appeared (event-based prospective memory). Because this particular event-based prospective memory task involved less deliberate processing given the external cue, age differences were not found. When no external cue was provided to trigger remembering as in the time-based task, age differences emerged.

Older adults themselves commonly describe their episodic memory problems as limited to remembering recent events. 'I can remember well what happened to me years ago; I just can't remember what I did yesterday.' This anecdotal self-description of memory problems implies stability for remote memories coupled with loss of recent episodic memories. There are problems, however, in studying very long-term memories. Older adults remember events from their remote past, but it is difficult to judge the accuracy of these recollections. Furthermore, they typically recollect salient events from the past that would be remembered regardless of when they occurred. And, finally, it is difficult to control for rehearsal (i.e., previous retrievals) during the long-term retention interval. When these variables have been controlled, research has shown that remembering is directly related to retention interval. Unlike the conclusion reached in the self-description, memory performance gets worse as the time between the original experience and the subsequent retrieval increases. This has been shown by collecting memory data at high school reunions, examining memory for foreign language skills learned in school over the life span, testing memory for the names of grade school teachers, and by examining autobiographical facts from diaries over an 18-year period. In these cases, there is some control of salience, good criteria of accuracy, and better control of rehearsal over the retention interval. The conclusion is clear: the older the memory, the more difficult it is to remember. It should be pointed out that while using retention intervals measured in years provides interesting data about remote memories, age is confounded with retention intervals in such studies. This constrains their interpretation in terms of understanding the effects of aging.

Semantic memory In order to remember something episodically, some aspect of the original encoding context has to be reinstated at retrieval. Often, however, we remember information without reference to how or when it was originally learned. We have access to a great deal of world knowledge that has lost all connection to the context of its original learning. 'Who was the first president of the United States?' 'What fruit is yellow and good with cereal?' 'What is your grandmother's maiden name?' Semantic memory is retrieved conceptually rather than contextually and represents accumulated organized knowledge.

Measures of semantic memory are often considered 'crystallized intelligence' on most intelligence tests. The general information test (answering questions such as 'What was Mark Twain's real name?') and vocabulary test (providing definitions of words) on the Wechsler Adult Intelligence Scale, for

example, measure access to conceptual knowledge. Few reliable age differences are seen on these tests, assuming educational level between age groups and other demographic variables are held as constant as possible. In fact, older adults often do better than younger adults on vocabulary tests until very late in life.

If young and old subjects were to differ in semantic memory, it most likely would reflect the way in which semantic memory was organized by the different age groups. There is little evidence, however, that the structure of organized knowledge differs in younger compared to older adults. One measure of semantic memory organization is the free association test. For example, words are given one at a time, and subjects are asked to come up with the first other word that comes to mind. If the associative structure of semantic memory differed between age groups, then this would be indicated by differences in responses given on free association tests. No age differences are found, however, in free associations to words, free associations to pictures, or in generation of category instances to category names such as 'fruit.' As mentioned earlier, older adults are less efficient and often take longer to retrieve semantic information, but the information in most cases can be ultimately retrieved.

Procedural memory Often memory has its effect automatically, without conscious awareness. 'Procedural memories,' once acquired, are automatic and do not require deliberate recollection at all. Once learned, we ride bicycles, type on our computers, and understand language without devoting a great deal of attention to the task. Procedural memories involve motor and cognitive skills.

Ingenious laboratory procedures have been developed to examine 'implicit memory,' procedural memory tasks that show memory effects even when subjects are not aware that remembering is occurring. For example, subjects first examine a list of words while performing some cover task such as rating the words for pleasantness. They then perform a series of other tasks unrelated to the word list seen earlier. Finally, they are given the task of completing presented word stems with any words that come to mind (e.g., 'por_____'). Compared to control subjects who did not read the words on the initial list, subjects that read those words will produce a word seen on the initial list more often, even though they are completely unaware that the word was presented earlier. If they are explicitly asked to use the word fragments to remember the words read earlier, large age differences are found. However, when asked instead to complete the fragments with any word that comes to mind and not implying a memory task, young and old show equal implicit memory. Age differences are typically not found on implicit memory tests, and when they are, they are very small compared to explicit memory differences. Longitudinal studies have also shown age change in explicit memory but no age change in implicit memory.

In summary, the memory systems approach has been very useful in describing when significant age differences in memory are found. It is also clear that even within one type of memory, age differences can vary considerably depending on the nature of the task and the nature of the processing required to perform the task. For this reason, memory researchers have been searching for better explanatory power in accounting for age differences seen in memory.

Resource Theory

A third view of memory assumes that there is a limited amount of cognitive resources that can be devoted to any cognitive task. If aging is associated with a reduction in cognitive resources, then memory performance should be detrimentally affected. To date there have been some successful attempts to measure deliberate processing using the process dissociation approach. The process dissociation approach uses separate indices of a memory task, one index that measures the amount of controlled processing (recollection) and the other that measures familiarity. Using this approach, age differences are found in the controlled recollection component of recall and recognition, while no age differences are found with the familiarity component.

Other investigators testing resource theory have adopted the correlational methods commonly used by individual difference researchers. The typical approach of resource theory is to identify resource mechanisms that can be independently measured, and then to determine their role in accounting for age-related variance in memory performance. The circles in **Figure 1C** represent the variance in measures of the three variables of interest: age, memory performance, and some measure of the cognitive resources. The overlap in the variance of age and memory performance is represented by the overlap in the two circles (i.e., $a + c$). The proportion of the age-related variance in memory accounted for by the cognitive resource variable is represented by the letter c.

Several different theoretical cognitive resource constructs have been proposed. Methodologically, in order to show that a cognitive resource mechanism can account for a significant proportion of age-related variance, the mechanism must be adequately measured at

the same time memory is tested. Then regression statistical techniques can be used to relate the mechanism to age and memory performance, as in the figure.

A proposed cognitive resource mechanism that has been proven fruitful in accounting for age-related memory performance is the working memory construct mentioned earlier. Assuming that working memory is a basic processing resource for engaging in remembering, then individual differences in working memory should account for individual differences in age-related, long-term memory performance. Regression analyses have shown that measures of working memory can account for more than 50% of the age-related variance in a variety of different memory tasks (e.g., free recall, paired-associate learning, text memory).

An even more basic cognitive mechanism, perceptual speed, has proven to be even more effective in accounting for age-related variance in memory. Perceptual speed is the ability to perform simple perceptual motor tasks, such as deciding whether two digit or letter strings are the same or different (i.e., number or letter comparison) or placing digits next to the appropriate symbol on a sheet by using an answer key showing the correct pairings of digits and symbols (digit symbol substitution task). Many studies have shown that very little age-related variance in memory performance remains after controlling for perceptual speed. One typically used memory task is the paired associate task, in which a subject recalls a response word that goes with a particular stimulus word after seeing the stimulus–response pair earlier during encoding. In one study, only 1% of the age-related variance in paired associate recall remained after controlling for perceptual speed.

It should be noted that speed and working memory are not mutually exclusive, or even opponent mechanisms in the search for understanding age and memory. In fact, studies have shown that variance in working memory itself is largely accounted for by the perceptual speed construct. In one study, statistical techniques of structural equation modeling were used to test the relationship among perceptual speed, working memory, and episodic recall. Using this technique, paths among the variables and their directional strength can be determined. It was shown that age had no direct effect on episodic recall performance when speed and working memory were included in the model. Age influenced recall in two ways, but only indirectly. First, age had an effect on perceptual speed that had a direct effect on recall. And second, age had an effect on speed that had a further indirect effect on recall through working memory. In other words, the best model in accounting for age-related differences in episodic memory performance in this case included the constructs of both perceptual speed and working memory.

Another candidate for a contributing mechanism to age-related memory performance is 'inhibition,' the ability to focus on target information by actively reducing attention to distracting, extraneous information. It has been suggested that as people grow older, they lose their ability to inhibit task-irrelevant information. The uninhibited information then reduces the available working memory capacity available for processing of the memory task. Decreases in inhibition have been demonstrated in a variety of different tasks. For example, when asked to read a text passage that has irrelevant information in a different type font interweaved throughout the passage, older subjects have greater problems in reading and processing the text.

In general, speed and working memory are considered to be basic mechanisms that measure resources available to perform cognitive tasks. In a sense, they measure neural efficiency. Research has shown that even sensory function that declines with age (vision and audition) can account for age-related variance in memory tasks.

Moderating Effects of Other Variables

Even more active than the search for cognitive variables that can mediate the relationship between aging and memory performance has been the attempt to find variables that can serve as surrogates for the relationship. Because most cognitive aging studies are cross-sectional (comparison of different age groups at a point in time), variables confounded with different age groups are candidates for these surrogates. For example, because subjects in different age groups were born at different times and therefore had very different life experiences, birth cohort is one such variable. To investigate this, memory performance must be studied as change within the same subjects rather than as differences across subjects. When cognitive abilities measured by psychometric intelligence tests were studied in this way, it was found that the cross-sectional age differences are typically overestimates of actual age change. Rarely, however, are cognitive age differences in cross-sectional studies eliminated when cohort designs are used. In fact, when longitudinal designs are used to study age change in laboratory memory tasks using longitudinal analysis, results similar to those found in cross-sectional studies are found. Age differences found with longitudinal designs look like differences found in cross-sectional studies when cohort and practice with the tasks are controlled.

More specific within-subject factors have also been examined as moderators of the age-memory relationship. Health, educational level, socio-economic status, and occupation have all been measured in conjunction with age. To the extent to which these factors influence memory performance, they can influence the size of age differences on memory tasks. Controlling these factors, however, does not eliminate the age effects. Health status, for example, can influence how one performs on memory tasks. However, even though health can influence memory performance, studies have shown that age differences in memory are not reduced much by controlling for self-reported health status. And even when more objective measures of health are used, such as the number of prescription medicines, only about 20% of the age-related variance in memory performance is reduced by controlling these factors. Controlling for health, therefore, can attenuate the relationship between age and memory but not eliminate it.

One criticism of research on aging and memory has been its reliance on controlled laboratory tests of memory. It has been suggested that these tasks are contrived and do not overlap with everyday memory tasks performed by older adults. Laboratory tasks are not relevant to older adults and therefore do not adequately reflect their memory abilities. In other words, memory research has been accused of not being 'ecologically valid,' because of the artificial, controlled nature of laboratory procedures. Laboratory memory tasks are seen as similar to the 'formal remembering' required in school settings and very unlike the everyday remembering engaged in by older adults. For this reason, younger adults may do better in these tasks because of their familiarity with situations used in the laboratory to test memory rather than because of their age per se.

Because of this criticism, there have been a large number of ecologically valid, everyday memory tasks used with different age subjects. Again, although using more familiar tasks can reduce age differences in memory performance, in most cases significant age differences are still found with everyday tasks. Such memory tasks as remembering faces, remembering facts from written stories, remembering a route taken through a town, remembering performed activities, remembering and understanding prescription medication information, and remembering grocery items all show memory differences favoring younger adults.

Furthermore, other lines of research suggest that differential familiarity or differential experience is not the critical factor in determining age differences in memory. Even when using older students and comparing them to younger students to control student status, age differences remain on a number of memory and cognitive tasks. There are also a number of memory studies using non-human animal subjects that show reliable age differences in memory performance, even though animal subjects of different ages shared identical everyday experiences since birth.

The conclusion emerging from these studies is that successful aging is not the absence of change, but rather the adaptation to change across the life span. Memory change appears to be a normal consequence of the aging process, and while non-cognitive factors such as motivation, health, or differential experiences can modify the magnitude of age differences in memory, rarely can these factors substitute for age itself in accounting for memory differences.

Interface of Cognitive Psychology of Aging with Other Areas

Individual Differences

As evidenced by the discussion of resource theory earlier, memory researchers are combining the methodologies of experimental cognitive psychology with the correlational techniques of individual difference research. Correlational techniques of regression, path analysis, and causal modeling are being used to determine what mechanisms are responsible for age-related variance in memory performance. The research so far has been consistent in pointing out the importance of perceptual speed and working memory as important factors in producing differences in memory performance.

These statistical techniques are not new; they have been used by individual difference researchers for a long time. What is new, however, is the use of the techniques to test hypotheses that have been developed in the experimental cognitive psychology laboratory. This combination of research traditions brings new promise to the study of aging and memory.

Cognitive Neuroscience

The same conclusion can be reached about the growing field of cognitive neuroscience, the interaction between experimental cognitive psychology (laboratory studies of memory) and neuroscience (studies of brain structure and function). With the development of functional neuroimaging techniques such as PET and functional magnetic resonance imaging (fMRI), brain activation can be measured while subjects are actually performing memory tasks.

Cognitive neuroscience research suggests that the prefrontal cortical areas of the brain are the locus for working memory. These parts of the cortex show unique activation when subjects are performing working memory tasks. Older adults show differential patterns of activity in the prefrontal areas of the brain while performing a working memory task.

Another area of the brain, the temporal-parietal area (hippocampal area), was hypothesized to be responsible for deliberate processing in long-term episodic memory. This conclusion, however, came primarily from the study of neurological studies of brain-damaged patients. These studies require autopsies before definitive evidence can be provided about the damaged brain areas that are responsible for the behavioral deficits. More recent neuroimaging studies have validated this conclusion, showing changes in the activation of this cortical area in older adults.

One of the major age differences found in neuroimaging studies of memory is a loss of asymmetry in the activation. Older adults show more bilateral activation with tasks that produce primarily unilateral activation in young adults. One suggestion as to why activation occurs in both hemispheres in older adults is possible recruitment of brain areas to compensate for brain losses.

In summary, both individual difference techniques and neuroscience techniques are expanding the methodological tools available for hypothesis testing by the research scientists studying aging and memory.

Conclusions

Memory changes as people grow older. The changes are selective, however, and primarily occur in working memory and in episodic memory. In general, the more self-initiated deliberate processing that is required to either encode or retrieve the information, the greater the age differences. Much of the age-related memory differences can be accounted for by simple cognitive mechanisms such as perceptual speed. Non-cognitive variables, on the other hand, do not seem to account for age-related memory differences.

See also: Attention; Dementia; Learning; Memory, Strategies; Neuroimaging (MRI, PET); Perception.

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Memory, Strategies

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Glossary

External Strategies – Methods for remembering that make use of tangible, physical objects, places, or people, for example, writing out a list of items to buy at the grocery store.

Internal Strategies – Methods for remembering that rely on internal mental processes, for example, creating mental images of items to buy at the grocery store.

Metamemory – Perceptions, beliefs, and knowledge about memory functioning in general, and one's own memory in particular.

Method of Loci – A formal memory technique in which a visual association is created between an item to be remembered and a location along a path through a familiar site (e.g., one's home).

Pegword System – A formal memory technique in which a visual association is created between an item to be remembered and a keyword (peg) that has already been learned in a familiar sequence, one such sequence being 'one is a bun, two is a shoe,' and so on.

Prospective Memory – Remembering to carry out intended actions.

Retrospective Memory – Remembering events that occurred in the past.

Rote Rehearsal – A method for remembering whereby items to be learned are repeated, silently or out loud, over and over again. Also called maintenance rehearsal.

Introduction

Memory strategies are techniques or methods for increasing the probability of remembering events in the past (retrospective memory) as well as events that are to take place in the future (prospective memory). A critical issue for gerontology is to understand the extent to which older adults can, and do, use effective strategies to remember. Knowing what strategies older adults actually use, and why they use them, can help in understanding the potential effects of age, cohort, and historical events on human information processing across the life span. The extent to which older adults can use effective memory strategies is important for improving older adults' quality of life by decreasing perceived need for dependent living, increasing self-efficacy, and reducing health risks. Furthermore, experiences of forgetting are among the most frequent complaints of adults as they age. Good strategies for remembering are numerous, and older adults do use some and have the potential to learn others that are effective. Research has shown that even people with Alzheimer's disease can benefit from instruction to improve their memory (*see* Memory).

Why Use Memory Strategies?

Development of Memory Strategies

Human memory is fallible and people are generally bothered when they forget, especially as they age. Indeed, a common myth about memory is that the best memory is one in which nothing is ever forgotten. However, there are significant pitfalls of having a so-called perfect memory, and the renowned case described by Luria of a person (called *S*) with an astounding memory demonstrated many of them. For example, *S*'s exact memory for people prevented him from recognizing them if they changed their clothing or had a different haircut. Of course, forgetting important things is not desirable, and high levels of forgetting are symptoms of a variety of problems, ranging from stress to dementia. Thus, memory strategies are valuable because, if they are effectively applied, they enable remembering things that one considers important and wants to remember but might otherwise forget. When a person adopts strategies to remember events, it indicates a high level of cognitive functioning. Proficient use of memory strategies is a sign of good cognitive management skills.

Throughout history, humans have devised innumerable methods for improving memory. These methods generally depend on the kinds of materials available as well as prevailing conceptualizations and models of mental activity. Consequently, the variety and use of memory strategies have changed over time. The oldest known memory strategy, the method of loci, dates back to about 500 B.C. and was attributed by Cicero to Simonides of Ceos, a poet. The method is a formal memory technique (also called a mnemonic) in which visual associations are created between items to be remembered and locations along a path through a familiar site (e.g., one's home). Then, to recall the items, one takes an imaginary walk along the path, and the locations cue memory for the items. It is a strategy that was devised to aid memory long before materials such as paper and pencils were available for writing lists and notes.

Today, a burgeoning commercial enterprise is designing, manufacturing, and selling devices to assist memory. Among these devices are reminder notebooks that include daily planners, calendars, expense records, and so on; electronic appointment books with programmable auditory and visual reminders; and pocket-sized electronic notebooks that can record spoken messages as well as respond to vocal requests to display stored information visually. In addition, some relatively new telecommunication devices are being used in novel ways as memory aids, for example, leaving messages for oneself on a telephone answering machine.

Relationship between Memory Strategy Usage and Memory Performance

The relationship between how good a person's memory is and the quantity and quality of strategies used has yet to be worked out. On the other hand, there is no dispute that effective strategies can significantly

improve memory performance. This improvement in memory has been demonstrated across a wide variety of memory strategies and materials to be remembered. Formal mnemonics, for example, have been shown to result in recall that can be two to seven times better than rote rehearsal. Combinations of memory strategies can produce impressive feats of memory. For example, young and older adults have been shown to be capable of increasing their digit spans (the number of digits in a sequence that can be remembered) from a typical average of between seven and 11 digits to 72 or more by creating associations between their existing world knowledge and groups of digits; by 'chunking,' or grouping, sets of digits; and by practicing these two strategies together in multiple sessions over an extended period of time.

Theories of how memory works offer some explanations for the relationships between the use of memory strategies and memory performance, although they generally only do so at a fairly global level. In the 'three-box' model of memory, for example, use of memory strategies affects whether information will be passed from sensory memory to short-term memory and, ultimately, to long-term memory. Information not passed from one stage of information processing to the next is thought to be lost, or forgotten. Furthermore, better use of strategies increases the likelihood of information being retrieved later. Thus, paying attention to information after it enters sensory memory leads to the information moving into short-term memory. Rehearsal is necessary to maintain an item in short-term memory, and more elaborate processing strategies increase the chances that the item will be stored in long-term memory for later retrieval.

According to the levels-of-processing model, items that are processed at a 'deeper' level (e.g., the semantic or meaning level) are much more likely to be retained than items processed at a 'shallower,' or more surface, level (e.g., the phonemic level). This theoretical approach has helped to convince memory researchers that rhyming, which depends on surface characteristics of words, is not a terribly effective memory strategy (*see* Memory).

Types of Memory Strategies

Strategies for remembering are typically employed when an event is deemed important enough to remember. Thus, more often than not, strategies are intentionally implemented, though with practice they may become quite automatic.

Memory strategies can be grouped in a number of different ways. The most commonly used categories include formal mnemonics, image-based strategies, general internal strategies, and external strategies. **Table 1** lists examples of each of these types of strategies.

Table 1 Types and examples of memory strategies

Internal memory strategies
Formal mnemonics
Acronyms (e.g., HOME for Great Lakes)
Method of loci
Linking items with a story
Pegword method
Imagery-based strategies
Bizarre images
Interacting images
General internal strategies
Alphabetical searching
Categorizing
Creating associations
Elaborating
Grouping
Rhyming
Rote rehearsal
External memory strategies
Address books
Appointment books
Asking others for reminders
Bookmarks
Calendars
Diaries
Lists (e.g., grocery)
Medication organizers
Object placement
Personal digital assistants (PDAs)
Photographs
Recipe cards
Reminder notes
Tape recorders
Timers
Video recorders

Formal Mnemonics

Formal mnemonics are systems for remembering that must be learned through instruction, generally because they are complex systems built upon an acquired core of knowledge. Formal mnemonic systems are analogous to the scaffolding of a building upon which the remainder of the house depends; they provide a framework on which to 'hang,' or incorporate, information to be remembered. Prototypical examples include the method of loci (previously described) and the pegword system. For the pegword system, visual associations are created between individual items to be remembered and keywords ('pegs') that have already been learned in a sequence, one such sequence being 'one is a bun, two is a shoe,' and so on. To recall the items, one uses the familiar sequence to cue the visual associations, which then call forth the items.

Active memory researchers, who are presumably familiar enough with the theoretical and empirical underpinnings of memory research to be considered experts on memory, eschew formal mnemonics for themselves and do not recommend them to others. Formal memory techniques require much effort to learn and constant practice to maintain. They are most readily applied to simple situations, such as learning a list of words, in which, unfortunately, their use is often outmoded by present-day materials and technology. For example, using the pegword system to learn a list of items to buy at the grocery story is unduly cumbersome when a written list would serve the same purpose and be much more efficient. Thus, although formal memory strategies can significantly increase the amount of information a person can recall, they are impractical for meeting people's needs for remembering in many situations of everyday life.

Image-Based Memory Strategies

Image-based memory strategies are methods for remembering that rely on internal mental processes of visualization. Examples include the creation of bizarre images and visualizing interacting images.

Memory psychologists report that they seldom use image-based techniques for remembering and that these techniques are among the ones they are least likely to recommend to others. Image-based techniques are also not spontaneously used by older adults. In general, older adults do not like to use memory strategies that they perceive as silly, and many of them consider creating bizarre images of relationships between objects as silly.

General Internal Memory Strategies

General internal memory strategies are methods or techniques for remembering that depend solely on internal mental processes. Examples include making an association between something familiar and an item to be learned, and organizing items into categories of objects that are similar to one another.

Three general internal strategies – rehearsal, categorization, and elaboration – are among those most frequently used and recommended by memory researchers. Rote rehearsal is the only general internal memory strategy that older adults tend to use spontaneously; in fact, it is their most preferred internal memory strategy.

External Memory Strategies

External memory strategies are methods or techniques for remembering that depend on tangible, physical objects, places, or people. Examples of external memory strategies that have wide applicability include lists, reminder notes, asking others for reminders, and object placement (placing objects where they will not be forgotten). And, instead of paper as the medium for notes, personal digital assistants (PDAs) are among the many modern technological devices that can be the vehicle for enhancing memory in a broad range of arenas. Other external strategies can be highly specific in their applications, for example, bookmarks, recipe cards, and organizers for sorting medications according to the schedule on which they need to be taken. Although external memory strategies are often called 'aids' rather than strategies, both internal and external memory strategies rely on higher cognitive functions for effectively reducing instances of forgetting.

Memory researchers report extensive use of external memory strategies. In fact, their favorite memory technique is to write things down, which has been referred to as 'the greatest memory strategy ever devised.' Although older adults claim to use external strategies frequently, they commonly view these types of strategies disapprovingly, as 'crutches.' They think that using techniques such as making a list or writing themselves a reminder note is 'cheating.'

Age Differences in Use of Memory Strategies

Empirical Findings

Research comparing the use of memory strategies by young and older adults demonstrates age-related differences in both the number and types of strategies people use. Compared to younger adults, older adults rely on a smaller repertoire of memory strategies. In addition to these quantitative differences, many studies report that the elderly tend to use fewer internal strategies and more external strategies than younger adults. What is interesting about this latter age-related difference is that external strategies are especially helpful for prospective memory, that is, for remembering to do something in the future, and this is one area of memory in which older adults often perform better than younger adults.

Learning how to remember new information is a primary, if not the primary, foundation of schooling. Students learn memory strategies while they are in school, and being in school furnishes an ongoing opportunity to learn and practice strategies for remembering. Not surprisingly, then, adults who are not in school rely on fewer, and less effective, memory strategies than adults who are in school. Older adults who are not in school even reject as valuable those strategies, such as categorization and grouping,

that are particularly effective for learning and remembering many kinds of information.

In the absence of being in school, other activities may provide an intellectually challenging environment that demands significant memory performance. Engaging in activities, such as the card game of bridge, may provide opportunities during later adulthood to continue to exercise the mental capacities required to learn and practice memory strategies. And research evidence suggests that older adults who do engage in activities that have high memory demands perform better on memory tests than older adults who do not participate in challenging activities.

Theoretical Considerations

When it comes to accounting for older adults' patterns of usage of memory strategies, theory is lacking. Studies have been primarily descriptive, reporting the results of surveys and questionnaires on older adults' ratings or rankings of lists of memory strategies in terms of how often they use them. While acknowledging that the elderly seldom spontaneously use some of the more effective strategies, such as categorization, researchers have turned their attention to determining possible benefits to older adults of instruction in how to use particular memory strategies. These studies demonstrate that elderly people can learn to use strategies that they do not typically use for a task, and that their memory performance can be significantly enhanced by applying such strategies. However, a remaining problem is that the resulting enhanced performance is often transient.

One highly plausible reason for older adults' infrequent use of those effective memory strategies that are very often used by today's young adults is that older adults may never have learned them before memory researchers came along to teach them. Sophisticated information-processing strategies are generally learned through formal educational experiences. The primary technique for remembering that today's older adults learned when they were children and young adults was rote rehearsal, and, as research has shown, it remains their favored strategy for remembering.

Beginning in 1879, with the work of Ebbinghaus, and continuing through the first half of the twentieth century, memory research was dominated by a preoccupation with rote rehearsal and the serial learning of lists of verbal materials, often specifically constructed to be as devoid as possible of meaning. Thus, it is not at all surprising that most of today's older adults, who were in school during the 1940s or earlier, learned that to memorize meant to practice rote rehearsal. In fact, it was not until the 1960s that a significant body of experimental evidence began to accumulate that confirmed the positive effects of categorization and grouping strategies on recall of verbal materials. These important historical facts relating to the development of thinking about, and use of, memory strategies must be recognized as critical factors in affecting the way today's older adults think about memory and the kinds of strategies they will tend to use when faced with a task requiring memory.

Instruction in Memory Strategies

Features of Instructional Programs

Contemporary instructional programs for improving memory come in different forms. Self-help books and tapes are becoming more and more numerous, and they are very popular. It is important to note that these instructional materials are commonly directed not at older adults, but at younger and middle-aged people in the business world, suggesting that the perceived need to improve one's memory through better use of effective strategies is recognized well before late adulthood.

Memory improvement programs typically contain an overview of how memory works, followed by separate lessons on half a dozen or more memory strategies. Each lesson includes a thorough description of a specific strategy with examples, followed by an exercise or assignment for practicing the technique. The techniques that are taught in instruction programs are almost always internal memory strategies, and all of the programs seem to include at least one formal mnemonic system. Although many of the self-help products have been on the market for decades, they have yet to be subjected to careful scientific scrutiny to examine the extent to which they work, assuming their lessons are actually followed.

Scientific studies of instructional programs for memory improvement have generally focused on teaching a single memory strategy in small group sessions conducted in an atmosphere similar to a classroom over a period of no longer than 4 or 5 weeks. These studies have demonstrated that older adults can learn new strategies and that their memory performance improves with the use of these strategies. On the other hand, the effects of these instructional programs often seem to be relatively short lived; older adults do not seem to continue to use these newly acquired strategies once outside the classroom.

Difficulties in demonstrating robust and lasting effectiveness of memory instruction may be primarily

due to three factors: an emphasis on internal strategies and formal mnemonics, the relative brevity of instruction, and the role of undispelled myths about memory and aging. Among the strategies most commonly taught to older adults is the method of loci. Despite its effectiveness with sufficient learning and practice, the method of loci, like other formal mnemonics, is not well suited to people's everyday needs for remembering because it requires much effort to learn and is not easily generalized to novel situations. Furthermore, the instructional period in scientific studies is usually brief relative to older adults' lifelong history of relying on only a select few memory techniques. To develop proficiency with new strategies, it is necessary to practice in sessions that are distributed over time and to get extensive practice in generalizing the use of a specific strategy to situations other than the one(s) for which it was learned.

Myths about memory and aging abound in our society, and belief in these myths has been shown to affect memory performance in older adults. Motivation and the effort to learn new, and more effective, memory strategies are certainly negatively affected by beliefs that significant memory losses are an inevitable consequence of aging. Without dispelling these myths, it seems doubtful that older adults could glean or maintain much benefit from instructional programs that focus on techniques alone.

Rather than teaching one or two formal techniques and hoping they will be applied to many different situations, instructional programs, research suggests, may be better off teaching a large repertoire of strategies from which older adults can choose those that work best for them. Because many of the most effective strategies have quite specific applications (for example, medication organizers), teaching a large repertoire also enables older adults to have many different strategies to call upon in different situations. Refresher courses also may be valuable in helping older adults to modify techniques that are not working well for them and to continue to augment their repertoire of strategies. Computer-aided instruction may have promise in this regard, although the problem of accessibility will have to be resolved first.

Unfortunately, few instructional programs teach about the wide variety of highly effective external memory techniques available and how to use them. What little research has been done in this arena indicates that the value of these techniques in the daily lives of older adults can be demonstrated immediately. In fact, it seems likely that instruction on external memory strategies would be even more effective if introduced with a discussion intended to dispel older adults' notions that external strategies are inferior methods for improving memory.

Finally, a good repertoire of strategies may require not only learning new, effective strategies, but also getting rid of old, counterproductive strategies. One such strategy, frequently used by older adults, involves storing valuable or important objects in 'special' places. This strategy results in significantly more forgetting than remembering. One reason is that the special place is specifically selected because it is a highly unlikely place for the object, which means that the person who put it there will, over time, be increasingly unlikely to remember to look for it in that location. Unfortunately, the fact that the special place is so unusual may also lead the person to be unduly confident that they will certainly remember where they put the object. This overconfidence then leads to the person ignoring effective memory strategies that could help him or her remember.

Value of Instructional Programs

There are obvious advantages to older adults, as well as to society, of offering instruction in memory strategies. They are all related to improving the quality of life of older adults. Advantages include maintaining older adults' independent living, improving their self-efficacy, and reducing their health risks, for example, through increased medication compliance. Evidence emerging from the research literature even suggests that instructing depressed and anxious people on how to improve their memory may help to alleviate their depression and anxiety (*see* Anxiety Disorders; Depression).

Too often, fears of family members and friends about an older loved one's perceived forgetfulness lead to premature, or unnecessary, institutionalization. Concerns about forgetting to turn off the stove, leaving the front door unlocked, or being stranded at night after headlights have drained their car battery can worry older adults as well as their families and friends. Appropriate instruction in the use of memory strategies and modern technology, however, can do much to alleviate these fears. Furthermore, instruction provides a more reasonable, appropriate, and economical alternative to institutionalization. For example, one can teach older adults how to effectively use lists and reminder notes to remember to carry out important actions in their everyday lives and to prevent memory failures that could jeopardize their safety. New products on the market furnish other means for reducing concerns about older adults' personal vulnerability, such as steam irons that shut themselves off after a short period of not being used, cars equipped with headlights that automatically shut

off within a few minutes of the ignition key being removed, and good medication organizers that can make it much simpler to monitor medication regimes.

Research has shown that even people with Alzheimer's disease can benefit from instruction to improve their memory. Psychological research and theoretical perspectives have already led to remarkable results in increasing specific instances of both retrospective and prospective memory in Alzheimer's patients. Using spaced retrieval, an instructional technique for improving learning and memory by gradually lengthening retention intervals with successful recall at shorter durations, Alzheimer's patients are being taught to remember names of common objects, face-name associations, and prospective memory tasks. The application of these methods for helping Alzheimer's patients to improve their memories is all the more significant because progressive memory loss is such a devastating aspect of this disease for the patients and their loved ones (*see* Dementia: Alzheimer's).

Such innovative, and successful, instructional programs provide convincing evidence that research on the benefits of memory instruction for improving the quality of older adults' lives is only just beginning and there is much more to be done.

See also: Anxiety Disorders; Dementia; Dementia: Alzheimer's; Depression; Memory.

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Menopause

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Glossary

Estrogen – The female sex steroid hormone, which is produced mainly by the ovary and placenta.

Follicle-Stimulating Hormone (FSH) – A polypeptide hormone from the anterior pituitary gland that is required for follicle growth and estrogen synthesis.

Luteinizing Hormone (LH) – A polypeptide hormone from the anterior pituitary gland that is required for ovarian steroid production and to trigger ovulation.

Menarche – The first menstrual period (menses), which occurs in the late stages of puberty.

Menopausal Transition – The few years preceding menopause when menstrual cycles become irregular and perimenopausal symptoms commence.

Menopause – The final period or menses occurring after natural depletion of ovarian follicles or from damage to or removal of the ovaries.

Ovarian Follicle – The developmental unit of the ovary consisting of an oocyte (immature egg) surrounded by somatic cells (granulosa and theca cells). It is responsible for estrogen production and, after ovulation, is reorganized to form the corpus luteum, which secretes progesterone and estrogen.

Progesterone – A steroid hormone mainly produced by the ovary and placenta.

Introduction

Menopause generally occurs in midlife while most women are still healthy and vigorous. The word *ménespausie*, meaning the cessation of menstrual flow, was coined in eighteenth century France; later it was shortened to ménopause and became adopted by the English language. Menopause is defined retrospectively after 12 months of amenorrhea as the last day of menses, although there is still a 5% probability of more cycles. The associated terms perimenopause and climacteric apply to the variable phase before and shortly after the last flow when estrogen deficiency symptoms are showing. Although menopause normally marks the final and irreversible termination of the female reproductive life span, fertility is not coextensive with menstrual cyclicity: there is relative subfertility in both the early and late years of the menstrual life span.

Menopause is a transitory biological phenomenon, but it also marks a social passage, the significance of which varies in different cultures. It has often been regarded as a negative reinforcement of the aging process and loss of sexual attractiveness. Yet, in some societies, past and present, it is considered a welcome relief from the burden of continuously bearing children and of menstruation. While biologists attempt to find ways of slowing the process of reproductive aging, many women are glad to embrace the change and regard it as an exciting new phase of life. This positive attitude surely bodes well for health care and enjoyment of the remaining decades of life.

Epidemiology

Age

The average age of natural menopause is remarkably consistent between countries and races (**Table 1**). The age distribution in a given population is wide and negatively skewed with a 5–95 percentile range of approximately 45–54 years (**Figure 1**). Menopause can occur at any age after menarche, although virtually all women are postmenopausal by age 60 years. The median age is a better expression of central tendency for population comparisons, being generally 49–51 years of age, although several years earlier in malnourished and historical populations.

Menarche and Socioeconomic Factors

During the past century, the age of menarche has fallen by 4 years to approximately 13 years of age in most developed countries, a trend that has now reached a plateau. This so-called secular trend is believed to be due to better nutrition, faster child growth, and changes in body composition, especially fat/lean body mass ratios. But there appears to have been little or no corresponding change in menopausal age over the same period, nor is there a correlation between the age of menarche and menopause. It appears, therefore that menopause is more independent than menarche of environmental factors, the corollary being that age-specific numbers of follicles in the ovary have probably been historically constant, in contrast to some evidence of declining sperm counts in men.

Table 1 Estimated median age of menopause in selected countries and races[a]

Country	*Year(s) of study*	*Race*	*Median age (years)*
Australia	1978	Caucasian	50.4
Czechoslovakia	1967	Caucasian	49.0
England	1951–1961	Caucasian	49.8
	1965	Caucasian	50.8
India (Punjab)	1966	Asian	44.0
Netherlands	1977	Caucasian	51.7
New Zealand	1967	Caucasian	50.7
Papua New Guinea	1973	Melanesian	47.3
Scotland	1970	Caucasian	50.1
South Africa	1971	African	49.7
	1971	Caucasian	50.4
Sweden	1974–1975	Caucasian	50.4
United States	1966	Afro-American	49.31
	1966	Caucasian	50.0

[a] Adapted from Gosden (1985).

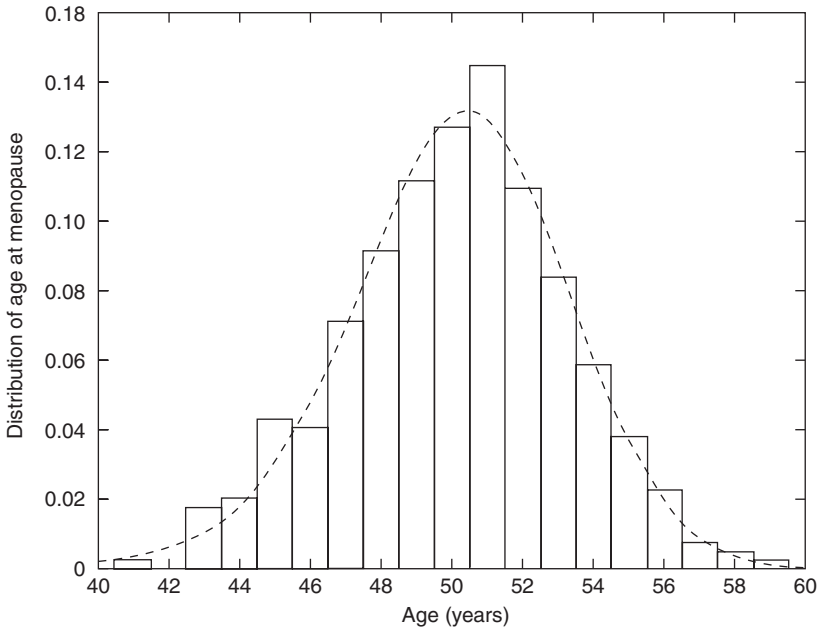

Figure 1 Distribution of ages at menopause in Caucasian American women. Adapted from Faddy MJ and Gosden RG (1996) A model conforming the decline in follicle numbers to the age of menopause in women. *Human Reproduction* 11: 1484–1486.

Genetics

A genetic foundation of menopause has been confirmed by the closer correspondence in timing in monozygotic twins than in dizygotic twins, and in blood relatives compared to unrelated persons. Moreover, a heritable tendency to undergo premature menopause can sometimes be attributable to genetic polymorphisms or mutations. Menopause is normally determined by many genes and, importantly, those that determine the formation of germ cells, the numbers of follicles, and the rate of follicle depletion by growth and degeneration (atresia).

Marital Status and Parity

There is little difference in menopausal age between women who have many children and those who have only one or none at all, although single women may have a slightly earlier menopause than married women. Since multiparity does not postpone reproductive aging and most follicles are lost by degeneration rather than ovulation, it is unlikely that steroidal contraception affects menopausal age, and most studies agree. On average, twin-prone women undergo menopause slightly earlier, but this cannot be caused by the higher ovulation rate since most follicles are lost by degeneration.

Tobacco Smoking

Menopause is advanced by 1–2 years in smokers compared to non-smokers and according to the number of cigarettes smoked. Tobacco smoke and tar constituents can damage the ovarian vasculature and damage follicle cells, polycyclic aromatic hydrocarbons being notable toxins that can interact with receptors in oocytes. The effects, if any, of recreational drugs on ovarian function and menopause have been less studied.

Disease, Drugs, and Radiation

Invasive diseases such as cancer and tuberculosis can spread to the ovaries and destroy follicles, hastening menopause. Less commonly, a viral infection may cause early loss of ovarian function. Ionizing radiation and some cytotoxic drugs, especially alkylating agents, destroy ovarian follicles in a dose-dependent manner and advance menopause in patients with cancer and autoimmune diseases. A radiation dose of only 2 Gray destroys half the follicle population and may temporarily cause amenorrhea; 20 Gray, or less in an older woman, causes irreversible sterilization.

Oophorectomy and Hysterectomy

Since the ovary is the principal source of estrogen in young, non-pregnant women, the surgical removal of both organs precipitates menopause. Removal of one organ or partial destruction has a small or only temporary impact on the menstrual rhythm, but it may shorten the reproductive life span. After uterine artery embolization or hysterectomy with intact ovaries, menopause may occur slightly earlier than normal if the ovarian blood supply is compromised.

Physiology

Ovarian–Pituitary–Hypothalamic Axis

Menstrual cycles depend on hormonal feedback between the ovaries and the hypothalamic–pituitary unit at the base of the brain. The pituitary hormones follicle-stimulating hormone (FSH) and luteinizing hormone (LH) are controlled by a decapeptide, gonadotrophin-releasing hormone (GNRH), which is secreted into portal vessels by neuronal terminals in the median eminence of the hypothalamus. Sequential and cooperative stimulation by FSH and LH is needed for the later stages of follicle growth and is obligatory for steroid production, ovulation, and luteal function. The length of the menstrual cycle varies between women and with age, having a median of about 28 days and with the luteal phase more constant in length than the follicular phase. It is determined by events in the ovaries, namely, the time to grow a follicle to maturity and the intrinsic life span of the corpus luteum.

Estradiol-17β is the most potent estrogen produced by the ovary, and the ovary is its principal source in non-pregnant, premenopausal women. Most of this hormone is produced by the dominant follicle destined to ovulate, and other follicles in the same cohort produce mainly androgens and undergo atresia before reaching maturity. Estradiol is produced by the cooperation between follicular granulosa and theca cells and requires stimulation by both FSH and LH (two-cell, two-gonadotrophin theory): LH promotes theca cells to secrete androgens, which diffuse to the granulosa cells where FSH promotes aromatization to estrogen. Growing follicles also produce the protein hormone inhibin B, which is a component of the negative feedback loop on pituitary function and is a clinical indicator of the size of the follicle reserve. When inhibin and estrogen levels rise in the follicular phase of the cycle, blood FSH declines, allowing only one follicle (or sometimes two) to survive to ovulation. In the absence of follicles after menopause, inhibin levels decline to near zero. Steeply rising estrogen from the dominant follicle triggers a positive feedback response from the pituitary by increasing both the pulsatility of GNRH secretion and sensitivity of pituitary cells. The surge of LH secretion triggers ovulation approximately 36 h later, and the collapsing follicle is remodeled to form a corpus luteum.

Actions of Ovarian Steroids

Steeply rising levels of estrogen during the follicular phase of the cycle stimulate the growth of endometrial glands and stromal cells in the uterus. They affect many organs and tissues, but especially those with high concentrations of estrogen receptors in the reproductive tract. The increased secretion of watery cervical mucins favors the survival and transport of sperm after coitus. At ovulation, estrogen levels temporarily fall and rise again from the corpus luteum, which produces much larger quantities of progesterone. This sequence of hormonal changes causes the endometrium to secrete a fluid that nourishes the embryo and becomes receptive for implantation. If conception fails to occur, the corpus luteum involutes, ovarian steroids decline precipitously, and the coiled vessels of the endometrium constrict, leading to menstruation. All of these changes are reversed after menopause – the uterine epithelium becomes thinner, the vaginal epithelium atrophies, and the rise in vaginal pH changes the bacterial flora. But they can be restored so effectively by treating with estrogen and progesterone that an embryo transferred from a donor can implant and establish a viable pregnancy in a postmenopausal woman.

The Follicle Population

Germline stem cells in the fetal ovary establish a fixed number of oocytes that combine with somatic cells to create more than a million primordial follicles at birth. According to conventional theory, these follicles cannot be renewed later in life. This store declines with age, faster during the last decade or more of the menstrual life span, until few remain at 50 years of age (**Figures 2** and **3**). Postmenopausal ovaries are normally completely sterile. Since there are normally only 13 ovulations per year in nonpregnant women and the average menstrual life span is 35 years, the great majority of follicles are wasted. Yet, many of the lost oocytes have fertile potential: they can be rescued by hormonal superovulation treatment, and, after *in vitro* fertilization (IVF), some produce embryos that are competent for pregnancy.

The Ovary and Estrogens After Menopause

Since the mature follicle is responsible for $>95\%$ of the circulating estradiol levels during the menstrual cycle, there is a profound fall in hormone levels after menopause. The postmenopausal ovary consists mainly of stromal tissue and fibrous remnants of corpora lutea (**Figure 3**). Surgical removal of postmenopausal ovaries has no significant impact on circulating estrogens, although the organs are a minor source of androgens.

A profound change takes place in the profile of circulating steroids after menopause (**Table 2**). The

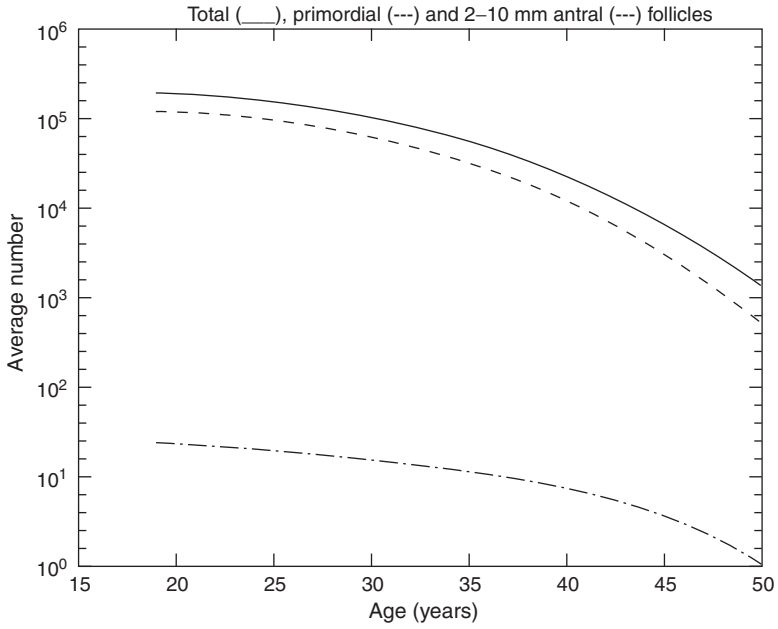

Figure 2 Numbers of follicles at different stages (total, primordial and antral) in human ovaries in relation to age (Faddy and Gosden, unpublished).

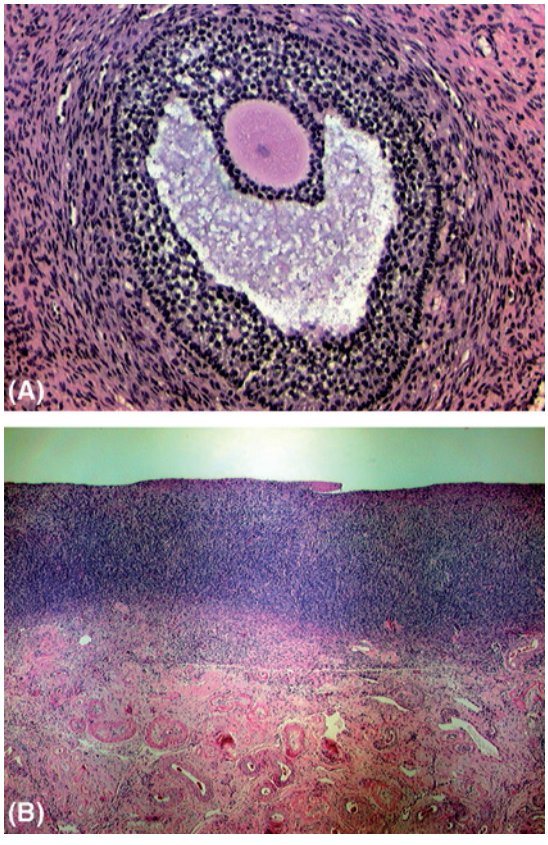

Figure 3 (A) High magnification of a growing follicle from the ovary of a woman of reproductive age showing a central oocyte surrounded by hormone-secreting granulosa and theca cells. (B) Low magnification of the ovary of a postmenopausal woman showing a complete absence of follicles.

principal estrogen changes from estradiol-17β to the less potent steroid, estrone, whose main source is extraglandular rather than the ovaries. Progesterone levels remain at a low plateau when ovulation ceases. The weak androgens, androstenedione and dehydroepiandrosterone and its sulfate, are mainly produced by the adrenal cortex and serve as precursors for conversion to estrone in adipose tissue, muscle, and other sites. In older women, there is a decline in the output of adrenal steroids. Body composition, especially adipose mass, affects the production of postmenopausal estrogens, which may account for obese women being slightly protected from hormone deficiency symptoms.

Perimenopausal Symptomatology

A wide range of symptoms is associated with the perimenopausal phase of life: hot flashes, nocturnal sweats, migraine, breast tenderness, palpitations, irritability, depression, and loss of sex drive. Symptoms of menopause are hard to dissociate from natural age changes, and none are absolutely specific to estrogen withdrawal. A majority of women experience some perimenopausal symptoms (80–85%), but the frequency is affected by cultural factors, domestic circumstances, and some medical conditions. The most common symptoms are vasomotor, which are centrally driven, physiologically inappropriate thermoregulatory reflex episodes. Since they are effectively treated by estrogen replacement

Table 2 Ovarian steroids during the menstrual cycle and following menopause[a]

Steroid	*Blood production rate (mg/24 h)*				*Peripheral plasma concentration (pg/ml)*			
	EF	*MC*	*ML*	*PMP*	*EF*	*MC*	*ML*	*PMP*
Estradiol	0.074	0.429	0.258	0.006	55	318	191	7
Estrone	0.133	0.265	0.236	0.040	60	120	107	25
Androstenedione	2.91	4.60	3.75	1.70	1450	2290	1870	930
Testosterone	0.152	0.345	0.207	0.150	220	500	300	300
Progesterone	0.682	4.44	31.13	–	310	2000	14 150	190

[a] Adapted from Gosden RG (1985) *Biology of Menopause: The Causes and Consequences of Ovarian Aging*. London: Academic Press. EF, early follicular phase. MC, mid-cycle. ML, mid-luteal phase. PMP, postmenopause.

therapy, they have a stronger claim of being dependent on hormonal changes at menopause. Flushing and nocturnal sweating generally begin a year or two before menopause, peaking shortly afterward and usually tapering off. Symptoms can be more intense after surgical menopause of younger women, probably because estrogen levels fall more precipitously than during natural aging. By this time of life, degenerative diseases – such as non-insulin-dependent diabetes, osteoarthritis, cancer – have begun their inexorable rise with age, but only osteoporosis resulting from bone demineralization appears causally related to estrogen withdrawal. Bone loss accelerates rapidly in the first few postmenopausal years before settling down to a moderate rate for the rest of life. It often goes unnoticed until an accident or compression fracture occurs years later. Men suffer the consequences of brittle bones later in life because testosterone levels are maintained longer than estrogens in women.

Menopausal Transition and Reproductive Aging

A staging system for monitoring pubertal development was devised many years ago by J. M. Tanner; recently, an attempt has been made to create an equivalent system for reproductive aging and the menopausal transition (**Figure 4**). A major problem with any classification is that not every woman goes through an identical sequence of stages from optimal fertility (-5) to ovarian senescence and postmenopause ($+2$), and there is a lot of variation in the age at which they enter stages and the duration. Some women have a prolonged phase of irregular cycles called the menopausal transition (stages -2, -1) before becoming acyclical, whereas others skip stages and have an abrupt transition from regular cycles to postmenopause. Generally, the menopausal transition lasts about 4 years from onset until menopause.

To the extent that follicle numbers decline continuously, reproductive aging can be considered to begin at birth, but it is more useful to consider the commencement of infertility, which is most clearly revealed from historical and contemporary populations that never practiced contraception (**Table 3**). The time taken to conceive, the incidence of miscarriage, and the frequency of birth defects and obstetric complications all increase gradually from about 30 years of age, and more rapidly at the end of the decade. By 40 years old, half the population is effectively sterile, even though most women can expect 10 or more years of ovulatory cycles. Yet, while cycles continue, the possibility of conception remains and contraceptive precautions should be considered. While the frequency of sexual intercourse and the quality of sperm have both started to decline by these ages, the ovaries are believed to be primarily responsible for the onset of reproductive aging, which manifest before other organ systems. Since fertility treatment involving egg donation from young women to older recipients produces high pregnancy success rates, oocyte aging is evidently the factor primarily responsible for declining fertility.

Menopausal transition is marked by variable cycle lengths of <20 days and >35 days interspersed with more normal cycles. Episodes of amenorrhea >60 days in duration become more common, as do anovulatory cycles. Also, the character of apparently normal 28-day cycles subtly changes in advance of the menopausal transition. Follicles grow faster in the early stages of the cycle and estrogen levels may elevate earlier, leading to a slightly truncated follicular phase. Serum FSH levels rise: levels exceeding 10 mIU/ml early in the cycle indicate that the ovarian reserve is becoming depleted and fertility is already reduced. Other serum biomarkers, notably inhibin B and anti-Müllerian hormone, are useful for estimating ovarian reserve, as are the clomiphene citrate challenge test and the antral follicle count from ultrasound scanning. None of these tests, however, can provide a long-range and accurate prediction of the timing of menopause.

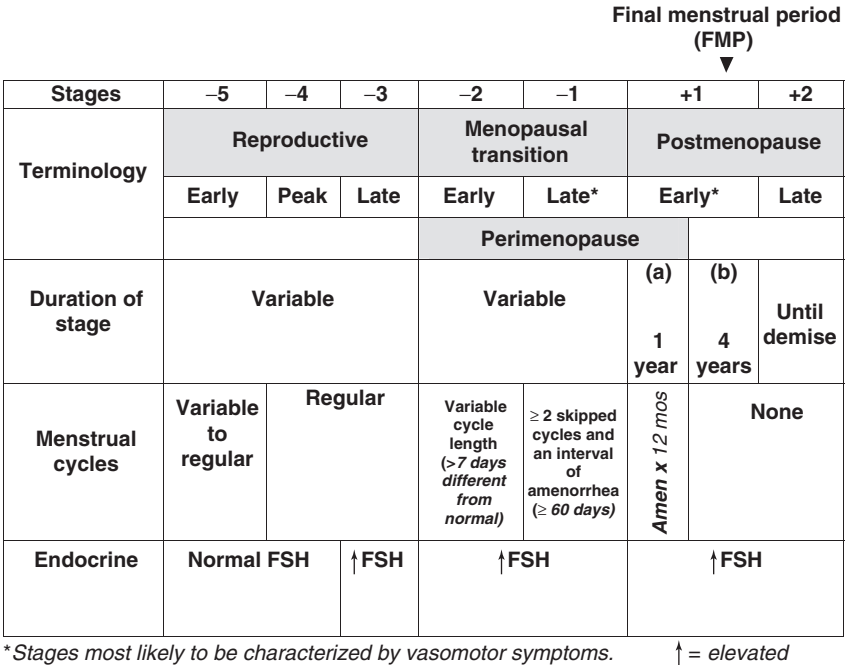

Figure 4 A staging system for the reproductive and postreproductive life span according to the Stages of Reproductive Aging Workshop (STRAW). Adapted from Soules MR, Sherman S, Parrott E, Rebar R, Santoro N, Utian W, and Woods N (2001) Executive Summary: Stages of Reproductive Aging Workshop (STRAW). *Fertility and Sterility* 76: 874–878, by permission of *Fertility and Sterility*.

Table 3 Fertility among the ethnic Hutterites of North America (1950s) by age group[a]

Maternal age (years)	*Live births/1000 women/year*	*Sterile couples (%)*
15–19	12	
20–24	231	
25–29	383	7
30–34	391	11
35–39	345	33
40–44	208	87
45–49	42	100

[a] Adapted from Tietze C (1957) Reproductive span and rate of reproduction among Hutterite women. *Fertility and Sterility* 8: 89–97.

Premature Menopause

In addition to significant numbers of young women undergoing medically induced menopause, about 1 in 100 spontaneously undergo premature ovarian failure (POF) before 40 years of age. Most causes of POF are unknown, but genetic and iatrogenic factors have been identified (**Table 4**). Some genes that are critical for germ cell formation are encoded by the X chromosome, and, since only one of a pair is fully active in females, the loss of a whole chromosome or a deletion or translocation can cause POF or even gonadal dysgenesis. The so-called Turner genes are in the pseudoautosomal region at Xp11-22, where both homologues are normally active. Another critical region for oogenesis is on the long arm of the X chromosome (Xq13-26), where the identities of several candidate genes are known. In addition, some genes associated with POF are encoded on autosomes, including *Fu/cL2, FSHR,* and *GALT,* which is involved in galactose metabolism; its mutation is associated with destruction of follicles. The symptoms associated with POF are similar to those of women undergoing the change at the normal age, namely, anovulation and hypo-estrogenism, but the overall health impact is greater. There are additional years of bone demineralization, and a study of American Seventh Day Adventists showed that POF was associated with a higher total risk of mortality at all postmenopausal ages.

Autoimmune damage involving infiltration of ovarian tissue with immunocompetent cells and circulating ovarian autoantibodies may account for up to 30% of all cases of POF. Oophoritis is sometimes associated with Addison's disease and thyroid autoimmunity, perhaps because other endocrine organs share common antigens with the ovary.

The most common iatrogenic cause of amenorrhea is hysterectomy, but if the ovaries are preserved, the benefits of cyclical hormone production continue almost until the normal age of menopause. In recent decades, there has been a steady increase in iatrogenic POF corresponding to the improving survival rates among cancer patients. As mentioned previously, some drugs and radiation damage the ovaries according to dose and age.

Table 4 Premature ovarian failure (menopause)

Category	*Types*	*Examples*
Karyotype	X chromosome monosomy, deletion and translocation	Xp11-22, Xq13-26 (critical regions)
Genic	X-chromosome	*FMR1* premutation, *BMP15*,
	Autosomal	*FOXL2, FSHR, GALT*
Autoimmune	Cell-mediated, ovarian autoantibodies	Addison's disease, thyroid autoimmunity
Iatrogenic	Reproductive surgery	Partial oophorectomy
Idiopathic	Cytotoxic treatment for cancer, etc.	Chemotherapy, radiotherapy

Comparative Biology and Evolution

Menopause occurs universally in women by middle age. Hence, women can look forward to at least one-third of their lives in a postmenopausal physiological condition. As a fraction of the maximum life span, the number of postreproductive years in our species is exceptional compared to virtually all other animals for which reliable data are available. In captivity, and occasionally in the wild, a few chimpanzees and macaque monkeys reach a brief postreproductive phase of life with elevated serum FSH levels and low estrogens, indicating that primary ovarian failure has occurred. Non-primates do not have menstrual cycles and, strictly, cannot undergo menopause; yet all animals lose follicles with age and, if they live long enough, will eventually become sterile and estrogen deficient.

From an evolutionary standpoint, menopause is perverse because it prohibits reproduction and further transmission of genes to the next generation, as well as potentiating some degenerative changes. Whether the explanation for menopause is that it is an artifact of civilization (i.e., through prolonged survival) or a species adaptation (kin selection) continues to be debated. Adaptive theories, such as the grandmother hypothesis, propose that, because of the greater obstetric risks of reproduction later in life, it is advantageous to sacrifice one's own reproductive potential and instead devote energy to assisting daughters and other relatives in rearing children. Although this evolutionary interpretation is challenged by many comparative animal biologists, the positive outlook on menopause is sometimes welcomed as a counterbalance to the generally pathobiological view of the medical community.

Treatment and Prevention

Hormone replacement therapy (HRT) is controversial because menopause is a milestone in a natural process of reproductive aging. Yet, the symptoms of estrogen deficiency are sometimes so distressing that women seek medical intervention; this is more important for women who undergo premature menopause. Treatment delivery options for estrogen replacement include oral, subcutaneous, transdermal, and vaginal routes, in doses adjusted to age, needs, and circumstances. Coadministration of a progestin in women with an intact uterus minimizes the risk of endometrial cancer but carries the disadvantage of reinitiating menstrual flow. The Women's Health Initiative study of more than 16 600 older American women using a formulation of estrogen plus progestin found that the health benefits did not outweigh the risks of cardiovascular disease, breast cancer, pulmonary embolism, and stroke. Consequently, HRT is now recommended for the shortest time necessary and at the lowest effective dose, and many women have sought alternatives, including greater physical activity, dietary supplements, non-steroidal medications, and complementary and alternative medicine. Vaginal dryness is an indication for topical treatment with estrogens, but, since sex drive does not abruptly stop after menopause, HRT is not an indication for improving libido. The benefits and long-term side effects of prescribing androgens for these women are still controversial.

Establishing pregnancy after irreversible ovarian failure requires the donation of oocytes or embryos from a fertile woman. These IVF procedures have in exceptional cases established pregnancies in women past the natural age of menopause, up to 66 years of age. On rare occasions, menstrual cycles and fertility have also been established after ovarian tissue transplantation between genetically identical twins or from tissue or eggs and embryos stored by patients before undergoing sterilizing treatment for cancer. Some women with autoimmune POF have been given corticosteroids to restore ovulatory function, but long-term treatment is discouraged. In experimental animals treated with cytotoxic drugs to destroy follicles, administration of sphingosine-1-phosphate has an ovary-sparing effect. Perhaps other inhibitors of germ cell death and follicle growth will be found that can slow the normal process of ovarian aging. This development might address the desire of increasing numbers of women who seek to defer childbearing to their less fertile years and to postpone menopause.

See also: Andropause.

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Mental Health

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Glossary

Comorbid – Disorders occurring together at the same time, such as in a patient who is experiencing depression, hypertension, and heart disease.

Meta-analysis – A statistical method of summarizing primary studies in order to understand the average finding.

Psychotropic – Acting on the brain's neurochemistry to affect psychological or mental functioning; psychotropic medications are drugs given to alleviate psychological symptoms such as depression, anxiety, hallucinations, or delusions.

Introduction

Mental health can be defined as freedom from mental illness. It can also be considered well-being or life satisfaction. The focus of this article is on the system developed to provide services to alleviate psychological suffering in older adults. Mental health care of the older adult in its optimum form is interdisciplinary, involving psychology, social work, psychiatry, and other fields, intertwined in a mental health-care system that delivers a wide variety of services. To more fully describe the mental health system in the context of older adults, the article discusses the populations of older clients in need of mental health services, what services are offered, the various systems

set up to provide this care, and the financial incentives that shape mental health-care services for the elderly (*see* Life Satisfaction; Psychological Well-Being).

Populations of Elderly Needing Mental Health Services

There are various populations of older people who may need mental health services. Some client populations clearly have mental illnesses that would be diagnosable at a younger age, whereas others develop disorders in old age; some might not even be commonly labeled as 'mentally ill' but can benefit from mental health care. The groups often need different types of services and settings for care.

The Severely Mentally Ill Elderly

The severely mentally ill elderly include older adults with schizophrenic and paranoid disorders as well as bipolar disorder and some severe or chronic cases of major depressive disorder. In 2001–02, the Centers for Disease Control and Prevention estimated that about 2.4% of older adults aged 65 or older had a severe mental illness. Diagnosis and severity do not necessarily predict the setting of care. Historically, older persons have tended to be overrepresented in inpatient psychiatric units and still account for about 16% of all psychiatric inpatients. The older patient has tended to remain on the inpatient unit longer as well, thus taking up an even more disproportionate amount of services, stays average more than twice as long for geriatric inpatients in state and county psychiatric hospitals when compared to younger adult inpatients. This has typically been attributed to the rising prevalence of organic brain syndrome diagnoses in the later years of life; however, depressive disorders make up a larger part of geropsychiatric admissions. Mentally ill elderly are also present in long-term care settings; more than 50% of the 1.6 million older adult nursing home residents have a diagnosable form of mental illness.

The Acutely Distressed Older Adult

The psychological problems of the acutely distressed elderly are likely to include depression, anxiety disorders, phobias, and sleep disorders. These problems are also likely to co-occur with medical illness and may therefore complicate medical treatment and lead to unnecessary medical visits and costs. This population is generally assumed to be best served in outpatient mental health settings, although they most often present themselves to medical settings such as primary care physicians (*see* Depression).

The elderly underutilize outpatient mental health services relative to their representation in the population. In 2001, fewer than one out of four older adults with mental illness and substance abuse disorders obtained any type of mental health care.

The Elderly with Dementia and Their Caregivers

The dementias affect about 6 to 8% of persons over 65. The prevalence of dementia doubles about every 5 years, and the prevalence for persons over 85 was found to be around 24%. The elderly with dementia represent about 50% of nursing home residents and are present in large numbers in residential care facilities and in community-based long-term care for the elderly. Older adults with early-stage dementia as well as caregivers of persons with dementia at all stages may benefit from outpatient services as well. Although the most widely recognized source of dementia is Alzheimer's disease (AD), it is important to note that dementia may be the result of many other conditions. Accurate neuropsychological assessment is crucial to differentiate among these disorders (and reversible sources of cognitive impairment such as delirium or severe depression).

The increased number of cognitively impaired persons among older adults, many of whom suffer from irreversible brain impairment, poses the dilemma of whether they should be categorized as mental health or medical clients. This decision has varied from state to state, as has the decision to separate the mental health service system from the systems for developmentally disabled and for substance abusers. The decision will have an impact on the type and scope of programming for the elderly. Given their different needs, older adults with dementing illnesses require types of services distinct from those with acute psychological disorders or psychoses. On the other hand, some older adults with dementia develop behavioral problems in the middle stages of their decline for which the treatment consists of psychotropic medications and behavioral interventions. These treatments are typically provided in the mental health system to people whose brain impairment began earlier in life. In addition, with the brain-impaired older person, as with others who are severely disabled, the caregiver may be in need of mental health services to be able to continue to care for the patient at home. The most common first choice for a caregiver is the spouse, generally older adults themselves, who may experience a wide range of needs in response to the caregiving situation. Prevalence rates of depression, anxiety, and hostility are extremely high in this population. Comorbid depression in dementia patients is associated with increased

disability, more functional and behavioral problems, and greater stress to caregivers. The prevalence of major depressive disorder in dementia has been estimated to range from 11 to 25%. Numerous studies have revealed that depression in dementia is mild, and is more commonly caused by cerebrovascular diseases than by Alzheimer's disease.

Results of different treatments for dementia are varied. Reality orientation is an intervention administered in a classroom-style setting to institutionalized individuals. Its goals are to reduce confusion and improve quality of life through the use of orienting tactics and mentally stimulating activities. Although its long-term effects are unclear, it has been shown to improve cognition and decrease mood symptoms in randomized control trials. Researchers also found memory training programs to be useful in improving recall and recognition abilities in demented patients, but treatment gains disappeared within 1 year. When patients are no longer capable of participating directly in therapy, caregivers can be enlisted to assist with implementing behavioral strategies such as increasing pleasant events to improve the mood of the patients. Other helpful interventions for caregivers include respite care, stress reduction training, and therapy for depression (*see* Caregiving and Caring; Dementia; Dementia: Alzheimer's).

Medically Ill Elderly

Certainly not all medically ill people require mental health care. The probability of physical disability and disease increases with age, creating patient populations with a high percentage of older adults, and many of these medical problems can cause psychological distress that is a legitimate focus of clinical attention. According to the Centers of Disease Control and Prevention, in 1995, arthritis affected almost 46% of those over 65, hypertension about 40%, heart disease about 23%, and deafness about 29%. These figures are even higher for those over age 75. In 2000, approximately $6140 was spent on medical expenses for each American 65 or over, compared to $2120 for those under 65. Depression is considerably more common among medical inpatients than in the population as a whole, affecting about one-fifth of patients. Illness-related functional disability is a good predictor of subsequent depression in community samples of older adults (*see* Arthritis and Rheumatic Diseases; Cardiovascular System; Hearing).

The hospital is a setting for many geropsychologists involved in health psychology, who deal with issues such as pain management, behavior management in cardiac patients, the effect of depression and anxiety on medical symptoms as well as depression itself in medical settings, adapting to loss of physical or cognitive functioning (e.g., stroke patients), and sex therapy for patients whose sexual functioning is affected by surgery or illness. Coping with chronic conditions such as heart disease, cancer, and stroke, the three leading causes of death in individuals over 65, is a focus of therapy both inside and outside of the hospital setting. Mental health intervention in medical settings is of particular interest to cost-conscious medical care providers such as health-maintenance organizations (HMOs) because successful treatment of clients can reduce excessive and unnecessary medical visits. Attention to mental status also may affect recovery from medical ailments. Early results from interventions for psychological distress related to medical problems are encouraging. For instance, Rybarczyk, Lopez, Alsten, Benson, and Stepanski showed that cognitive behavior treatment (CBT) resulted in improvements in self-report measures of sleep at posttreatment and 4-month follow-up among older adults with chronic illness and comorbid insomnia. Rybarczyk, DeMarco, DeLaCruz, Lapidos, and Fortner assessed an intervention that included education on mind–body relationships, relaxation training, cognitive restructuring, problem solving, communication, and behavioral treatment for insomnia, nutrition, and exercise. The intervention resulted in reductions in sleep difficulties and an increase in health behavior, which were maintained at 1-year follow-up. Given the complex interplay between psychological and medical origins of adjustment to and recovery from medical disorders, more research is needed on treating psychological distress related to medical problems.

Anxiety Disorders

Although anxiety disorder rates are lower for older than for younger adults, they are more prevalent than mood disorders among older adults. Information about rates of mental disorders among older adults is scarce, and researchers often rely on the Epidemiological Catchment Area survey data collected in the 1980s. Among individuals over 65, the 1-month prevalence rate for anxiety disorders was 7.3%, compared to 5.1% for affective disorder. Phobic disorders were found to be the most common anxiety disorder, affecting about 6.2% of the population. On the other hand, figures from a community study of inner-city residents over 65 indicated a prevalence rate of 15% for all anxiety disorders. Despite the copious amount of research done on the subject of anxiety, late life anxiety remains a largely unstudied area (*see* Anxiety Disorders).

Although medication is often employed as a first-line treatment for anxiety disorders, empirical evidence for the psychological treatment of anxiety

disorders has begun to emerge. In numerous studies, CBTs were found to be generally effective in treating anxiety disorders among older adults, and the effects were often maintained at follow-up. Mohlman, Gorenstein, Keber, de Jesus, Gorman, and Papp demonstrated that adaptations of CBT for older adults, through inclusion of memory aids and frequent review of treatment techniques, resulted in a further increase in treatment effectiveness. Relaxation training is another common intervention for anxiety disorders; it has been found to improve self-reported psychiatric symptoms and decrease trait anxiety among older adults.

Sexual Disorders

The sexual response changes with normal aging. Many older adults do not expect these normal developmental changes and misinterpret them, leading to a decrease in sexual activity and enjoyment. Psychoeducation can aid the older adult understand and adapt to these normal age-related changes. Many older adults also must cope with illness-related changes in sexual functioning. Chronic disease-related pain (such as with diabetes or cancer) can interfere with normal sexual functioning. Sex therapy can aid the older client to adapt to the losses in sexual functioning and maintain a satisfying sex life. A barrier to this is often the therapists' discomfort with discussing sex with older clients or the misperception that the topic of sexuality is inappropriate to discuss with older adults. This is unfortunate because the majority of older adults welcome information and discussion and are not uncomfortable with the topic. Just as in younger adults, however, some older adults do exhibit sexual disorders of a deviant nature (exhibitionism, pedophilia, etc.), which are an appropriate target of intervention, either by the mental health-care system or by the legal system (*see* Sexuality, Sensuality, and Intimacy).

Substance Abuse

Substance abuse in later life can be considered an appropriate target for mental health system intervention. For example, alcohol abuse is a major problem among older men and is a legitimate mental health problem, as is the abuse of both illegal and prescription drugs. Older adults commonly are on multiple prescription medications and experience side effects or drug interactions. Older adults who abuse alcohol are at risk for physical health problems and psychiatric comorbidity such as anxiety, depression, and cognitive impairment. Long-term use of alcohol may lead to behavior problems, exacerbation of a previously existing personality disorder, or organic brain disorders, such as Korsakoff's syndrome, that can be distinguished from other dementing illnesses by comprehensive neuropsychological assessment. Misuse of over-the-counter (OTC) medications can cause problems in the elderly, who are more sensitive to medications. The most common substance abuse disorder is tobacco dependence; it accounts for more medical disability and mortality in the elderly than all other substances combined. Polysubstance use disorders may be a problem for many elderly who are using prescription medications, OTC medications, and/or alcohol. In reviewing available treatment options, Schonfeld and Dupree reported cognitive and behavioral interventions to be more effective than 12-step and social support models in treating alcohol abuse and dependence among older adults. Carstensen, Rychtarik, and Prue found that treatment gains from a behavioral treatment for older males were maintained at 2-year follow-up.

Services Offered in the Mental Health System

Psychological Testing

Assessments of cognitive functioning or personality are a specialty of clinical psychologists; those specifically trained to work with older adults are in a position to be able to accurately test and interpret results for this population with its higher frequency of sensory or other cognitive limitations and cohort differences. Assessments are done in response to a number of needs, such as diagnosis of any type of mental illness, differential diagnosis of depression or types of dementia, diagnosis of functional abilities after stroke, or forensic work, such as establishing competence or incompetence for a court of law. Neuropsychological testing is often done with older adults; this type of assessment uses special tasks to try to determine level of functioning of cognitive abilities such as verbal and visual memory, speech, spatial ability, or reasoning. Different disorders or locations of brain injury show different patterns of deficit on the various tasks, which aids in diagnosis.

Psychotherapy

The most commonly recognized form of mental health-care services is probably the provision of individual psychotherapy in either the inpatient (hospital) or outpatient (clinic or private practice) setting, but there are many other forms of mental health care provided to the elderly. In the outpatient clinic or the inpatient psychiatric facility, individual therapy is only one of a number of therapy modalities, such as

group therapy, support groups, family therapy, and couples therapy. Two types of therapies that are not unique to but are more often used with older adults are life review and grief work. These services are provided by psychiatrists, psychologists, social workers, and counselors.

Medication

A large segment of mental health care is provided in the form of psychotropic medications, which are prescribed by psychiatrists or primary care physicians. According to Lebowitz and Niederehe, most elderly present their symptoms to a primary care physician; about 70% of physician visits by those 75 and older resulted in at least one prescription, and 44% received multiple medications. Ten percent of physician visits by those 65 and older resulted in a psychotropic drug prescription. Ninety-five percent of visits resulting in prescriptions for psychotropic medications were made to non-psychiatrist physicians, mostly primary care physicians. Additionally, over half of nursing home patients are prescribed psychotropic medications, 20% of these without recording of an appropriate diagnosis. Psychotropic medications are therefore not only prescribed by psychiatrists, but also by non-specialist physicians, which highlights the importance of effective coordination of care. Some interdisciplinary teams use clinical pharmacologists to advise proper medication usage due to their knowledge of medication action and interaction in the elderly (*see* Pharmacology).

Case Management

Case management is another form of mental health-care service to the elderly. This service helps the frail or cognitively impaired older adult with referrals to professionals in any field, coordination of service providers, household help, help with legal or financial matters, and various other tasks. Case managers are often social workers, nurses, or gerontologists.

Social Services

Social activities and centers or services set up to provide seniors with social interaction are often organized and funded by aging-related agencies and sometimes are staffed by mental health-care professionals or paraprofessionals. Examples of these are congregate meal sites, friendly visitor programs, and senior recreation centers.

Problem-Specific Services

Problem-specific services are also an important part of mental health-care delivery, especially to the elderly, who most often experience specific challenges rather than general loss. Day care for dementia patients and respite programs for caregivers are two examples of programs tailored to the specific needs of older adults. Other types of specific services are bereavement and widowhood counseling and support, and specific interventions designed to decrease geropsychiatric inpatient stays.

Health Psychology and Other Hospital-Based Services

Hospital-based mental health-care services cover a wide range of psychological and psychiatric issues and modalities, such as consultations, assessments (both neuropsychiatric and psychological), psychotropic medication, pain management, individual counseling on a wide range of medical or psychological issues, work on treatment adherence (most notably in cardiac patients), rehabilitation training, self-help groups or therapy groups for patients with specific disorders such as breast cancer, social services, and discharge counseling.

Do Treatments Work?

Many of the services and treatments provided to older adults have been shown empirically to be effective. There is still a great need for studies validating treatments on special groups such as the elderly, but a number of meta-analyses (quantitative summaries of a number of studies on the same topic) have supported the use of psychological treatments such as CBT, brief psychodynamic therapy, and pharmacotherapy for depression, as well as other interventions to aid caregivers of dementia patients. Non-quantitative literature reviews suggest that effective interventions exist for insomnia, the dementing elderly, and the severely mentally ill. The need for this type of outcome research will continue to grow as reimbursement agencies like insurance companies want support for the efficacy of services provided.

Models of Service Provision and Systems of Care

Multiple Systems of Care for the Elderly

Appropriate placement of older adults, even when they have the same diagnoses as younger patients, introduces some complexities. In terms of long-term care for the elderly, there is an age-based system and a system for the mentally ill. Placement of the mentally ill elderly is a complex issue: are they best served in the mental health system or the aging care system? Older people often have complex chronic and acute medical needs. Nursing homes for older adults are

equipped to handle chronic medical issues and some psychiatric issues, such as mild dementia, but are often not able to handle more severe behavioral problems, psychotic residents, or suicidal residents. Psychiatric facilities, on the other hand, are often not equipped to handle the complex medical needs of the older patient. The staff of psychiatric facilities often do not have the medical expertise to care for the elderly, and the staff of age-based long-term care facilities do not know about psychological or psychiatric issues; they do not effectively coordinate with each other either. This issue is also salient in assessing and interpreting assessments of older adults, who often perform differently on tests and require different norms than younger adults, especially when accounting for overlapping comorbid medical conditions or sensory limitations.

The notion of ranges of care within separate care systems can organize our thinking about the institutional environments for the elderly. It has been argued that conceptually and legally separate systems of care for the elderly exist. The long-term care system for the elderly as defined by licensing regulations moves from independent living to residential care and locked residential care, intermediate care, skilled nursing care, and locked skilled nursing care. The psychiatric system could be viewed as including acute psychiatric hospitals, state hospitals, and locked skilled nursing facilities. Based on the preceding discussion of coexisting medical and mental health problems, the acute medical care system must also be considered as a third system of care through which older adults with psychological problems also move. The medical system provides an interesting example of care that is more integrated with the corresponding outpatient care and that serves as a gateway to long-term care.

There are several problems in considering the range of care within any of these systems as a progressive hierarchy. First, patients enter and leave the system and move from level to level in a wide variety of ways. The popularly accepted view may be that the elderly gradually deteriorate and progressively move up the scale, but reality fails to confirm this image. For example, dementia patients who also have behavior problems may move from independent living to high levels of locked care and then move to more 'independent' levels of care as their physical condition deteriorates and they are no longer capable of causing trouble. The rationale for movement within the three systems is also different. Movement within the aging long-term care system is based on physical frailty and functional ability in terms of the activities of daily living (ADLs). Movement within the psychiatric system is based on the degree of acuity of the psychiatric disorder, the overtness of behavioral problems, or both. Movement within the acute medical care system (and from acute to chronic or long-term care) is based on diagnosis, response to treatment, and intensity of need for nursing care. Thus, three interlocking but conceptually distinct systems with built-in tensions exist and are bound together by serving some of the same patients and many similar patients. Mental health patients, former mental health patients, and the cognitively impaired inhabit all levels of care in all three systems. The ideal goal for the person who serves elderly clients is to seek the level and type of service required by the patient's condition and to avoid unnecessarily restrictive placement. The concern with avoiding inappropriately restrictive and excessively costly treatment has led to a focus on community-based care. Although the distinction is more salient in some systems than others, for most services there is a dividing line between 24-hour care and community-based care systems.

Problems in Care Delivery That All Systems Must Address

What are some of the problems that prevent older adults from receiving care in the most appropriate location? Assessment of mental health problems in older adults can be complex due to the array of possible presenting problems and the high rates of comorbidity. Specialized training in assessment of older adults is desirable and can be obtained in graduate, postgraduate, or continuing education settings. Moreover, some elderly may simply not see their problems as psychological, or they may be unaware of the existence of outpatient therapy. A second pervasive source of complexity is that older adults with mental health problems are embedded in a variety of distinct care systems at both institutional and community-based levels: medical care, long-term care for the elderly, mental health services, aging network services, and possibly dementia care services. Professionals need to be aware of other agencies' waiting lists and available services so that referred clients do not 'fall through the cracks.' Unfortunately, due to limited resources and shrinking budgets, agencies' eligibility requirements for services are strict, and it may prove difficult to find agencies that can accept clients, leaving areas of need unfulfilled by any of the service providers. Difficulties in coordination of care may therefore be a function of economic pressures rather than planning failures (*see* Health Care and Services).

The complex needs of the older client will necessitate working with a range of professionals, such as aging network service providers, health-care providers, and the legal system. This need for interdisciplinary

and intersystem cooperation requires both conceptual understanding of how systems work together and practical training in manipulating complex systems for the good of the client. The interdisciplinary approach also requires respect for and understanding of other professionals in diverse fields. It should be common in the geriatric mental health team setting to find all members listening intently to valuable perspectives about clients offered by volunteers, nurses' aids, homemaker aides, and meal-site workers. In fact, the usual economies of health and social systems dictate that those with the least training and status will have the greatest actual exposure to the client and therefore the best opportunities for behavioral observation (e.g., the client's physician sees him or her 5 to 10 minutes a month, the home health nurse, half an hour per week, and the homemaker aide, 8 hours per week).

Program Principles in Mental Health and Aging

Fortunately there are guidelines available for providing more appropriate services to older adults. High-quality, community-based mental health services for the elderly share some common features:

1. All emphasize accurate diagnosis of older adults.
2. All are interdisciplinary and treatment focused.
3. All use active case-finding methods and community education approaches to bring clients in. They also collaborate actively with other agencies that serve older adults, and in some cases with postal carriers, meter readers, and other 'community gatekeepers.'
4. All of them deliver mental health services to older adults at home.

These are key elements of successful community-based programs in mental health and aging. The Veterans Affairs (VA) system provides a model for hospital-based care. Like the community-based programs, the VA emphasizes accurate assessment, active treatment, and interdisciplinary coordination of services. Many VA mental health services are provided in medical settings (acute wards, chronic care, nursing homes, etc.) as well as in distinct psychiatric units. Home-care services are also a part of the VA continuum of care. Furthermore, the VA has played a major role in developing training in geriatric mental health across the constituent disciplines.

Other model programs are those that focus on problem-specific outreach services for older adults. Specific problems are more salient than generic loss; programs that target specific needs and offer services to meet those needs are well utilized. This schema for relating programs to needs and populations grows from the discovery that utilization of outpatient services in community mental health programs was uncorrelated with utilization of inpatient services by the elderly. Four programs that have been successful are senior outreach teams, family-based services for dementia care, intensive case management, and day treatment services for the older adult. These programs are tailored to the needs of the different subpopulations of the elderly who need mental health services. Throughout this range of programs, the outreach principles of educating the clients, educating the providers, and improving the availability, accessibility, and affordability of services will help to assure that those in need understand and use effective mental health interventions.

The key issue in the continued development of services to older adults is their affordability. Most program development in mental health services for the elderly has taken place in contexts that do not rely entirely on fee for service or on Medicare funding. Other sources of funds have included state funding for mental health services, community mental health system funding, VA funding, training grants, research grants, and grants from various private, non-profit agencies. These sources can be motivated by perceived client need, interest in creative program development, and training goals.

Payment Systems and Their Impact on Service Delivery

Since about 1980, there has been a privatization movement in mental health care characterized by an increasing reliance on private practice providers and organized for-profit systems that are driven by market forces such as demand for services and the need to profit from service provision. This has led to the development of what has been described as a medical-industrial complex comparable to the military-industrial complex.

The main source of money for mental health services for the elderly is still government funding (75%, mainly from Medicare and Medicaid). The Medicare health insurance program provides coverage for inpatient psychiatric care, partial hospital care (i.e., day treatment), and outpatient psychiatric services delivered by qualified Medicare providers. The Omnibus Budget Reconciliation Acts (OBRA) of 1981, 1989, and 1990 resulted in the lifting of the annual cap on reimbursement of outpatient mental health-care services and provided for direct payment of clinical psychologists and clinical social workers; however, certain services are still restricted. The 1989 OBRA changes have led to increases in Medicare spending on inpatient psychiatric care, including an

expanding number of geropsychiatric inpatient units. In terms of the principles of care outlined previously, this program has the advantage of emphasizing assessment and encouraging the development of services at several levels of care throughout the nation. The ability of fee-for-service Medicare to produce rapid changes in service delivery to older adults by a wide spectrum of service entities with minimal administrative overhead is its greatest strength.

Despite such policy revisions, recent figures indicated that Medicare specialty mental health service policies continue to falter in promoting service use among older beneficiaries. For instance, Medicare spending on mental health accounted for less than 4% of total Medicare spending. Slightly more than half of these expenses covered the service use of disabled beneficiaries who were under 65 and constituted only 14% of the Medicare beneficiary population. Although the 1989 OBRA changes promised increased access and use of outpatient services, Medicare continues to require that beneficiaries assume a 50% co-payment for outpatient mental health care, compared to a 20% co-pay for medical care.

Another significant problem is that Medicare allocates a much higher amount for inpatient care than day treatment and outpatient services, hence it fails to provide sufficient services in the least restrictive setting possible. Medicare allocated approximately $3.2 billion for inpatient psychiatric services in 2001, and slightly more than $1.2 billion for day treatment care and outpatient mental health services in 1998. Medicare regulations have also tended to discourage, if not eliminate altogether, home visits for mental health services. Interdisciplinary cooperation is present to the extent that communication with the primary care physician is encouraged, but this falls short of working in an interdisciplinary team setting. The emphasis on inpatient care tends to exacerbate the existing imbalances of older adults in inpatient versus outpatient care and is bad mental health policy in any case because outpatient care is generally more effective and less expensive. The impact of Medicare through the fee-for-service reimbursement model seems to have been to expand mental health service delivery to older adults dramatically and to encourage the privatization of mental health care for older adults, with a built-in predilection for the encouragement of inpatient over outpatient options.

Summary

The mental health system for older adults is still evolving. Although some differences in mental health care for older adults are due to specific problems (especially dementia), the largest differences lie in the mental health-care system itself: in specialty services provided to older adults, in the dilemmas faced by elderly with comorbid conditions, and in the systems of payment for mental health services. The response to the needs of the elderly has included a number of specific services geared to this population and the extension of services originally developed for younger adults to the elderly via active outreach and case finding. The future of mental health services for older adults will be influenced by new knowledge and techniques from research and program development, by the growing number of specialists in mental health and aging, and by the continuing evolution of mental health policy, especially changes in Medicare.

See also: Anxiety Disorders; Arthritis and Rheumatic Diseases; Cardiovascular System; Caregiving and Caring; Dementia; Depression; Health Care and Services; Hearing; Life Satisfaction; Pharmacology; Psychological Well-Being; Sexuality, Sensuality, and Intimacy.

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Metabolism: Carbohydrate, Lipid and Protein

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Glossary

Adaptation – Acquisition of a new steady state in response to environmental change.

Allosterism – A regulatory mechanism that involves ligand binding. A cooperative interaction that occurs when a ligand binds at a site distal to the catalytic site and influences (inhibits or enhances) the activity of the catalytic or active site of an enzyme or receptor or transporter. In general, allosterism results from interactions among subunits of multiunit proteins, and these interactions determine the activity of the total protein.

Anabolism – Reactions or reaction sequences that result in synthesis of macromolecules such as glycogen, proteins, triacylglycerols, and so on.

Apoptosis – Programmed cell death.

ATP – Adenosine triphosphate; a high-energy compound that functions in energy transfer within the cell.

Catabolism – Reactions or reaction sequences that result in degradation of macromolecules to their smaller component molecules.

Citric Acid Cycle (Krebs Cycle) – Cyclic series of reactions that enables cells to oxidize metabolites and that results in the production of reducing equivalents for use by the respiratory chain and citrate, which can be transported to the cytosol for hydrolysis to oxalacetate and acetyl CoA. This cycle takes place in the mitochondria.

Gluconeogenesis – Synthesis of glucose from two and three carbon metabolic intermediates. Gluconeogenesis is stimulated when the intake of glucose is deficient or when glucose is not being metabolized by cells. This occurs in the disease *diabetes mellitus*. Gluconeogenesis takes place in the cytosol and shares many of its reactions with glycolysis.

Glycogenesis – When more glucose is provided to the body than can be immediately used, some of this glucose is stored in the form of glycogen through a series of reactions beginning with glucose-6-phosphate and ending with a branched glucose polymer. Glucoses are joined by linkages between carbon 1 and carbons 4 or 6.

Glycogenolysis – When the body is in need of glucose it raids its glycogen stores through glycogen hydrolysis.

Glycolysis – The main pathway for the use of glucose by the cell. This use begins with the phosphorylation of glucose and, through a series of enzymatic steps in the cytosol, results in the production of the three-carbon molecule, pyruvate. If oxygen is in short supply, pyruvate is converted to lactate, pyruvate enters the mitochondria for further use by the citric acid cycle.

Homeostasis – A condition of constancy within the living animal characterized by the steady state maintenance of metabolism where anabolic and catabolic pathways counteract each other as appropriate for the nutritional, environmental, and hormonal condition of that animal.

Lipogenesis – Synthesis of fatty acids from acetyl CoA and the esterification of these fatty acids to glycerol to make triglycerides. Lipogenesis occurs in the cytosol.

Lipolysis – Cleavages of fatty acids from glycerol usually followed by the oxidation of these fatty acids and the reuse of glycerol. Lipolysis occurs in the cytosol, whereas fatty acid oxidation occurs in the mitochondria.

Membrane – Lipid bilayer consisting of phospholipids and cholesterol. Proteins, which serve as receptors, carriers, or enzymes, are embedded in this bilayer, either wholly or partly.

Metabolic Control – Regulation of metabolic processes with the result of optimal efficiency of energy and metabolite conservation.

Mitochondria – Organelle responsible for energy transformation. The citric acid cycle, respiratory chain, oxidative phosphorylation, and fatty acid oxidation occur in this compartment.

Nucleus – Organelle of the cell that contains the genetic material, DNA. Gene codes for almost all the proteins synthesized by the cell are in this cell component.

Pentose Phosphate Shunt – When glucose is consumed in excess of need, some of the glucose is metabolized by way of this shunt. This series of

reactions yields two reducing equivalents per molecule of glucose used. These reducing equivalents are used in the *de novo* synthesis of fatty acids. The shunt also produces ribose-5-phosphate, an important constituent of RNA, and three carbon intermediates, which can enter the glycolytic sequence. The shunt takes place in the cytosol.

Respiration and Oxidative Phosphorylation – Series of reactions that results in the joining of oxygen to hydrogen to make water. Respiration produces energy, which is trapped (under closely regulated conditions) in the high energy bond of adenosine triphosphate (ATP); ATP, in turn, transfers this energy to the synthetic processes of the cell.

Steady State – A characteristic of a living system in which all fluxes are maintained to optimize that system's survival. It is an open system that has maximum thermodynamic efficiency.

Ureogenesis – Cyclic series of reactions for the synthesis of urea from ammonia.

Introduction

Aging is a continuum of metabolic change from conception to death. As cells multiply and as differentiation occurs, the needs for specific nutrients (substrates) and fuels change. Hormones, genetics, and nutrients interact and affect the orchestration and regulation of this process called growth. Upon the attainment of full maturity, subtle changes in this regulation occur such that the system is maintained with little or no growth of new tissue. There are exceptions to this; adipose tissue fat stores can increase given an energy surplus and in the adult female, pregnancy and lactation are processes that inherently are characterized by the growth of new tissue. Of concern to this article is the regulation of metabolism in the postmaturation phase of life; that is, the postreproductive period of the female and the equivalent time period in the male.

The regulation of carbohydrate, lipid, and protein metabolism is an integrated process that occurs at many different levels in the body. Metabolic regulation is, in fact, the summation of all those processes and reactions that ensure a continuous supply of fuel and substrates necessary to sustain life. It includes both anabolic and catabolic processes that use or release energy and use or produce needed substrates or end products. Living organisms survive and thrive when all of these processes are interdigitated and synchronized. Characteristic of aging is a gradual, subtle, and not so subtle loss in this synchrony. How this loss occurs is the subject of much discussion. The pattern of loss is not the same in all individuals, although some similarities do exist. Genetic differences, gender differences, and species differences influence the gradual loss in metabolic control and the gradual loss in the homeostatic mechanisms that assure continuance of life.

Nuclear DNA

Although it is generally assumed that healthy life span is genetically dictated as well as modified by dietary conditions, no one gene or group of genes has been identified that is directly responsible for life span determination. Researchers interested in the aging phenomenon as well as those interested in the genetic aspects of age-related degenerative disease have found age-related changes in both nuclear and mitochondrial DNA. DNA, although a very large molecule, is also a liable one. When in solution, it decomposes at the liable N-glycosyl bond. In living systems this permits base substitutions and deletions (mutations) to occur, and if sufficient numbers of these occur, aberrant gene products will result that can explain in part, the age-related losses in particular cell functions. Nuclear DNA, although subject to hydrolysis, oxidation, and non-enzymatic methylation, can repair itself. **Figure 1** illustrates where damage can occur. The base substitutions can be reversed by a series of reactions shown in **Figure 2**. In young animals this repair is quite efficient. However, one of the consequences of aging is a loss in DNA repair efficiency. It should be noted that mutations are spontaneous and occur randomly. Not all cells or cell types are affected, nor does the process occur all at once. Losses in cell function occur cell by cell, and cell types differ in their vulnerability and in their repair capacity. Nonetheless, with age there are changes in DNA that result in functional losses. With this loss is a rise in the presence of methylated cytosines, base deletions, base substitutions, and strand breaks. All of these deviations from normal are biomarkers of aging (*see* Markers of Aging). Of interest is the observation that food-restricted animals have fewer DNA aberrations than ad libitum fed animals of the same age. Food-restricted animals live longer than non-restricted animals when both sets of animals are housed under the same conditions and are fed the same diet and are of the same genetic background. Should the genetic background differ,

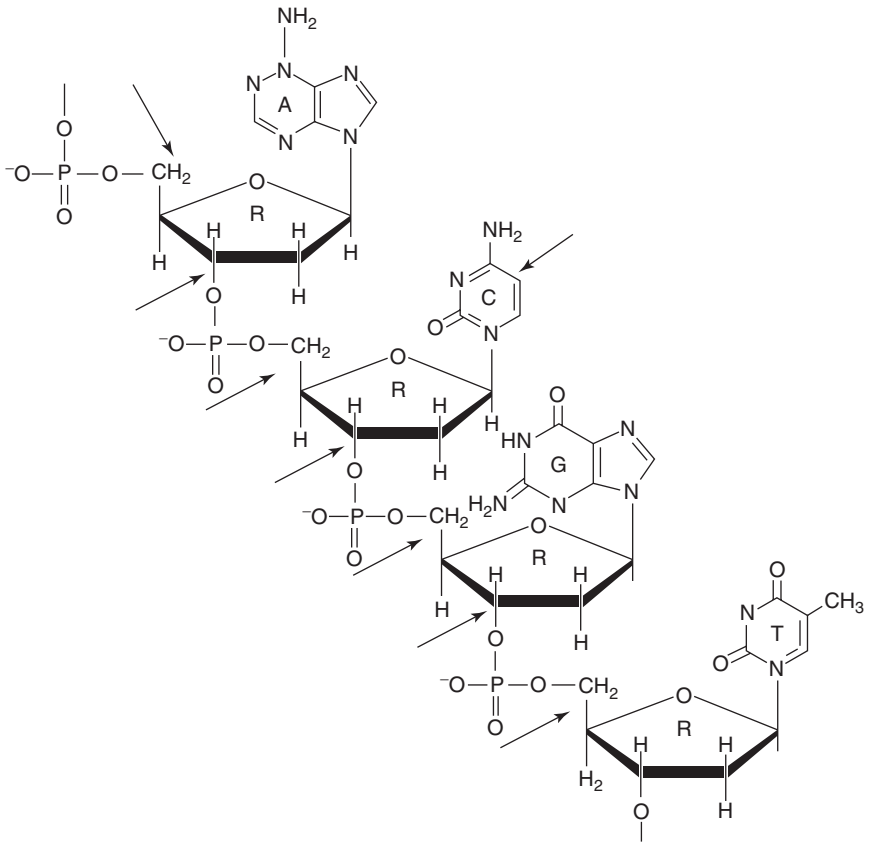

Figure 1 The bases that comprise the DNA polynucleotide chain are joined together by phosphodiester bonds using ribose as the common link between the bases. A, adenine; C, cytosine; G, guanine; T, thymine; R, ribose. Labile sites for DNA damage are indicated by arrows.

the difference in life span due to food restriction will also differ. In other words, although life span can be increased with food restriction, length of life will ultimately be controlled by the genetics of the consumer. Rats from short-lived strains will die sooner than rats of long-lived strains, and rats of both strains will live longer when food is restricted. Those of the long-lived strain when food is restricted will live longer than those food-restricted rats of the short-lived strain. This probably also occurs in other species; however, there is the caveat of environmental control. Larger animals, and humans in particular, cannot be maintained in controlled environments where infections are minimized and climatic conditions are ideal. Furthermore, the complexity of human life with its social and economic demands does not lend itself to a stress-free environment.

Mitochondrial DNA

Nuclear DNA damage is forestalled in many instances by its protective histone coat. Mitochondrial DNA lacks this protection. Furthermore, mitochondrial DNA has limited repair capability. Mitochondrial DNA carries only a few messages when compared to nuclear DNA, yet should wholesale damage to this DNA occur, the results could be devastating. That damage occurs is without doubt, but seldom is the effect of this damage devastating. This is because each cell contains many mitochondria; the liver cell, for example, contains about 800. In addition, although cell turnover might be slow to non-existent in some tissues, mitochondrial turnover is much more rapid. Thus, although mitochondrial DNA repair is limited, the larger number per cell and turnover rate compensate for damage that might occur to a single mitochondrion or indeed to a group of mitochondria within a cell.

Normal aging is characterized by an accumulation of deletions in mitochondrial DNA. Different tissues accumulate these deletions at different rates. Deletions have been found in human skeletal muscle, liver, skin, neural tissue, and cardiac muscle. Skeletal muscle from humans shows a 10 000-fold increase in deletion over the course of a normal life span. In the

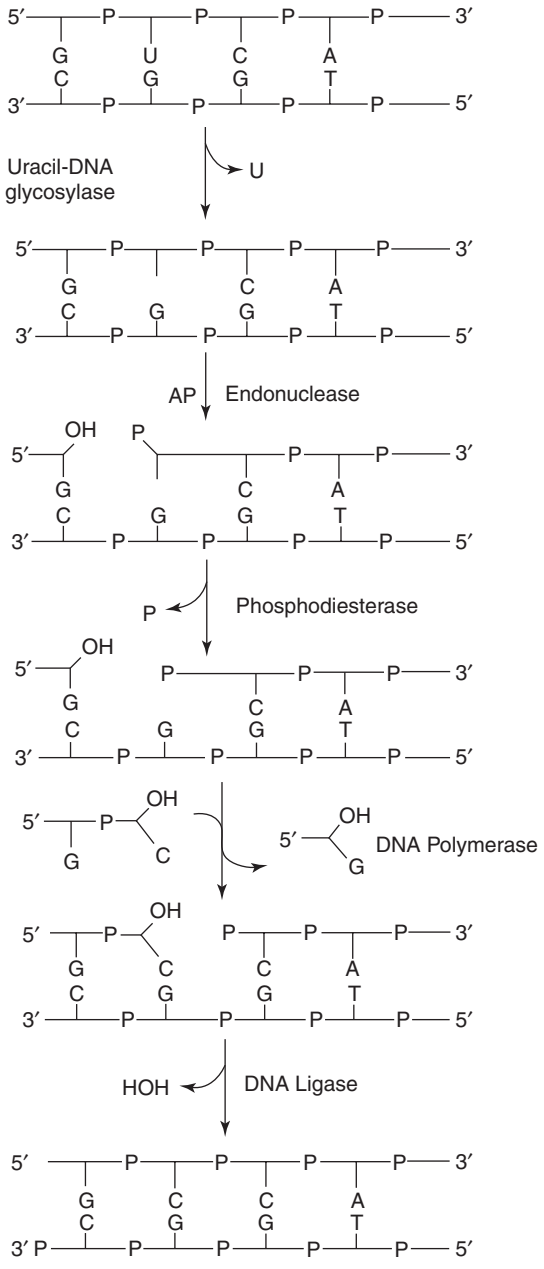

Figure 2 DNA repair. Shown here is the excision of uracil and the base-free deoxyribose phosphate, followed by replacement and correction of the missing residue by DNA repair synthesis. The glycosylases recognize the base substitution and remove it (step 1). These enzymes also recognize bases that are methylated and oxidative damage. Cell viability is dependent on the presence of these glycosylases.

rat, the increase in deletion is more rapid in hepatic and cardiac muscle cells than in skeletal muscle cells. The deletion mutation in the mitochondrial genome has been attributed to free radical attack on the labile N-glycosyl bond. Free radicals can readily form in the mitochondrion because of its structure and function. The mitochondrion is comprised of two dual membranes that are rich in phospholipids, which contain a high percentage of fatty acids as polyunsaturated fatty acids. Because the mitochondria consume about 90% of all the oxygen consumed by the cell, and because this oxygen is usually in its ionic or charged state, there exists ample opportunity for free radical formation. With age, lipid peroxide levels rise in a variety of tissues from humans, mice, and rats. These very reactive substances attack the DNA, resulting in deletions. In turn, as the number of deletions accumulate, cell function and then organ or tissue function is compromised as the mitochondria lose their ability to respire and synthesize ATP. This sequence of events has been suggested as an explanation for heart disease, accelerated aging due to diabetes mellitus, renal disease, Parkinson's disease, and Alzheimer's disease.

Membranes

The membranes serve as geographical boundaries of cells and cellular compartments. These structures are composed of phospholipids arranged in a dual layer with their hydrophilic aspects facing outward, and their hydrophobic aspects facing inward. Cholesterol is also part of the membrane and provides a measure of lipid structural stability. Four major phospholipids are found in these membranes: phosphatidyl choline, phophatidyl serine, phosphatidyl ethanolamine, and phosphatidyl inositol. Each of these phospholipids has fatty acids at carbons 1 and 2, and at carbon 3 of the glycerol backbone there is a phosphate group to which is attached either choline, ethanolamine, inositol, or serine. These structures comprise the charged portion or hydrophilic portion of the phospholipid. The fatty acids at carbons 1 and 2 comprise the hydrophobic portion of the molecules and provide the fluidity that is characteristic of a membrane. Fluidity is conferred by the ratio of saturated fatty acids to unsaturated fatty acids, and the ratio of these fatty acids to cholesterol. When the content of unsaturated fatty acids rises in a membrane, the membrane could become more fluid. This is compensated for by a rise in cholesterol. This compensation ensures a constancy in membrane fluidity. However, not all membranes are similarly regulated. The plasma membrane is carefully controlled in this way but the mitochondrial membrane is not. There is very little cholesterol in this membrane, thus this membrane

can vary substantially. Diets rich in polyunsaturated fatty acids will affect the mitochondrial membrane to a greater extent than the plasma membrane. With age there is a gradual reduction in the fluidity of membranes as subtle shifts in the ratio of saturated fatty acids to unsaturated fatty acids occurs. This in turn affects those cell functions that are dependent on fluidity (*see* Cholesterol and Cell Plasma Membranes).

The membrane phospholipids create the environment for protein function. Just as these lipids are amphipathic so too are the proteins. The proteins are distributed in a non-uniform fashion throughout the lipid bilayer. Some are anchored in the surface facing the plasma, others face the cytosol, and still others are inserted through the bilayer. Most of these peripheral and integral proteins do not interact directly with the phospholipids that surround them, yet these lipids can have effects on their function. In some instances these lipid effects are due to their fluidity. Proteins that function by changing shape would be less able to do so when surrounded by relatively rigid lipids. Changing membrane fluidity would thus result in changing the ease with which these proteins could change their conformation and hence activity. An example of this influence is the effect of plasma membrane fluidity on insulin receptor activity. Where the membrane is more fluid because of polyunsaturated fatty acids in the diet, the numbers of receptors available for binding and their binding affinity are increased. Another example relates to the mitochondrial membrane. In rats fed highly unsaturated (fish oil), moderately unsaturated (corn oil), moderately saturated (beef tallow), or very saturated (hydrogenated coconut oil) fat, mitochondrial respiration coupled to ATP synthesis is very efficient in the first group with gradual losses in efficiency observed in the subsequent groups. Both the enzymes of the respiratory chain and the many subunits of the ATP synthetase are embedded in the mitochondrial membranes and, in membranes that are very fluid, these proteins have optimal flexibility and function. Similarly, the transporters of the metabolites and adenine nucleotides that are required for optimized oxidative phosphorylation are likewise optimized in a more fluid environment.

Although the diet fat can have these influences, hormonal influences can be just as strong. Hypothyroidism is characterized by increased fatty acid saturation and decreased function of both plasma and mitochondrial membranes. Characteristic of hypothyroidism are derangements in carbohydrate use, notably a decrease in glucose oxidation, decreased protein synthesis, and accumulation of fat in the adipose tissue. Decreased thermogenic capacity characterized by an inability to maintain body temperature in a cold or chilly environment also characterizes hypothyroidism. Heat production results when ATP is synthesized. Thus, if ATP synthesis is reduced, so too is heat production. Providing a hormone replacement will reverse all these features. The membranes will become more fluid, and ATP synthesis will increase. Heat production will increase partly due to increased mitochondrial activity and partly due to an effect of ATP on protein synthesis that in turn has effects on skeletal muscle activity. Altogether, then, hormone replacement has a cascade of effects that appear related or integrated by the hormone's effect on membrane fluidity and function.

Other hormones likewise have effects on membrane phospholipid fatty acid saturation and fluidity. Growth hormone, the glucocorticoids, insulin, glucagon, the sex hormones, and some of the pituitary hormones (e.g., ACTH and thyroid-stimulating hormone have been found to influence membrane function through effects on membrane composition). In some instances, these effects are indirect. That is, the hormone in question stimulates the synthesis of fatty acids in the cytosol. Because these fatty acids rapidly exchange with those in the membrane phospholipids, there are effects on fluidity via this mechanism. Other hormones may stimulate the lipolysis. This results in a release of fatty acids from the stored triacylglycerides, which in turn can exchange with the phospholipid fatty acids in the membranes. Many of the catabolic hormones (i.e., glucagon, glucocorticoids, etc.) act in this way to influence membrane composition and function (*see* Endocrine Function and Dysfunction).

Age has a profound effect on membrane lipid saturation and fluidity. As animals age the membrane fatty acids become more saturated, fluidity falls, and those enzymes, carriers, and signaling systems that depend on a fluid environment become less active. In addition to changes in fatty acid saturation, the cholesterol content rises, and this lends a further degree of rigidity to the system. Thus, age-related declines in membrane-associated reactions or pathways may be attributable in part to these age changes in composition without regard to diet or hormonal perturbations. The latter can modify the age changes either suppressing or magnifying them as described above.

In addition, there are age changes in free radical production and suppression. With age, there is a decline in oxidative phosphorylation efficiency. Mitochondrial respiratory activity declines with the result that there is greater opportunity for superoxides and

fatty acid radicals to form. These very reactive substances can react with the mitochondrial DNA as well as with the various proteins in this organelle, causing damage and loss of function. Hepatic mitochondrial respiratory function has been shown to decline with age, as has the biosynthesis of mitochondrial inner membrane proteins. Mitochondrial DNA mutation has been shown to rise with age and increase in peroxidized lipids. These changes have cumulative effects on carbohydrate, lipid, and protein metabolism.

Intracellular and Intercellular Communication

Hormones and their secondary messenger systems are the central integrators of the communications that exist between the brain and the rest of the body and between the different organs and tissues. With age there is a decline in the efficiency with which these communications are transmitted. This is due to a myriad of age-related structural and functional changes. Aging is associated with anatomical changes of the endocrine glands. Some glands, the ovary for instance, have a defined life span and the cells are programmed to cease functioning at midlife. Programmed cell death, apoptosis, is both genetically determined and nutritionally influenced. With age there is a general decline in gene expression (translation and transcription) with a related decline in the accuracy and efficiency of protein synthesis. In part this is due to the age-related accumulation in DNA mutations due to free radical damage. Protein turnover also declines with increasing age, and this is manifested by an age-related increase in protein half-life (*see* Cell Death).

Many hormones are proteins, and as such one might expect that age will have effects on their synthesis, release, activity, and degradation. Best studied is the protein hormone, insulin. With age the pancreas becomes less responsive to signals for insulin release, and the target tissues become less responsive to its action. In part this may be due to age-related increased plasma membrane phospholipid saturation, but it is also due to age-related increase in fat cell size. As fat cells accumulate stored fat they become less sensitive to the action of insulin in promoting glucose uptake and use. Muscle cells likewise may have age-related changes in membrane fluidity that impair their response to insulin. As well, there is an age-related decrease in muscle use. Working muscles have little need for insulin bound to its receptor to facilitate glucose use. Altogether then, this decrease in muscle activity plus the increase in fat cell size has a negative effect on the insulin–glucose relationship. Glucose levels rise and the β cells of the pancreatic islets of Langerhans increase their output of insulin to meet the glucose challenge. However, this excess output does little good in reducing the blood glucose in the aging, overly fat, inactive individual, and it is not uncommon to have noninsulin-dependent diabetes mellitus develop as a consequence. Age-related impaired glucose tolerance can be mitigated by food restriction and increased activity that reverses the above physiological state. Because insulin is one of the main regulators of intermediary metabolism and because its action is counterbalanced by the glucocorticoids, the catecholamines, the thyroid hormones, glucagons, and several other hormones, it should be no surprise that age changes in these hormones occur as well. Again, some of these changes can be attributed to age changes in membrane lipids, but some can be attributed to changes in hormone production and in the synthesis and activity of the receptors that mediate their action. **Table 1** lists some hormones affected by age. The blood levels of most of these hormones decrease in the aging human and laboratory animal. A few pass through a phase where they are elevated above normal then fall below normal as aging continues. All of these hormones serve to regulate the metabolism of carbohydrate, lipid, and protein.

Table 1 Hormone changes with age

Hormone	*Age effects*
Serum thyroxine (T_4)	↓
Serum triiodothyronine (T_3)	↓
Thyroid-binding globulin	No change or ↑
Thyroid-stimulating hormone	↓
Insulin	↑ followed by ↓
ACTH	↓
Epinephrine	↓
Glucagon	↓
Growth hormone	↓
Estrogen	↓
Testosterone	↓
Cortisol (glucocorticoids)	↓
Pancreatic polypeptide	↑

↑, increase; ↑, decrease.

Fuel Fluxes

Although all nucleated cells carry the same genetic messages for enzymes and constituents, many of these messages are not transcribed and translated. Thus, certain cells have special functions or processes that are their unique properties, whereas other

cells appear to be more versatile. Adipose cells for example, synthesize and store triacylglycerols; kidney and liver cells synthesize glucose via gluconeogenesis; liver and muscle cells synthesize, store, and use glycogen as a fuel. Renal glomerular cells or tufts filter the blood, the central nervous system does none of the above and is unique as a central integrator of communication. Age has unique effects on each of these tissues and their respective metabolic processes. The pathways of intermediary metabolism are outlined in **Table 2**. Each of these pathways has specific control points that in turn are affected by age. Although various studies have shown age-related declines in enzyme activities, it should be remembered that these are *in vitro* measurements in conditions where substrates and coenzymes are in optimal amounts to assure saturation. This rarely occurs *in vivo*. Hence, a decline in activity may not mean a decline in *in vivo* function. In a number of instances the age-related decline in activity of a pathway or reaction can be inhibited by chronic food restriction. This inhibition of aging effects on metabolism probably has to do with the decreased fat stores that are the result of food restriction. A decrease in fat store reduces the supply of fatty acid precursors to free radicals, and this may lead to a reduction in error rates in the genetic material as well as a reduction in protein damage with resultant loss of function. In addition, a reduced fat store has effects on peripheral cell responsivity to insulin vis-á-vis glucose use and of course, in the absence of hyperinsulinemia, there is a decreased release of the anti-insulin hormones. As described earlier, age-related alterations in hormone balance do occur, and these alterations have an impact on carbohydrate oxidation, glycogen storage and mobilization, hexose monophosphate shunt, and gluconeogenesis.

Table 2 Effects of age on intermediary metabolism and its control

Pathway	*Control points*	*Effects of age*[a]
Glycolysis	Transport of glucose into the cell (mobile glucose transporter)	↓
	Glucokinase	↓
	Phosphofructokinase	↓
	α-glycerophosphate shuttle	
	Redox state, phosphorylation state	
Pentose phosphate shunt	Glucose-6-phosphate dehydrogenase	↓
	6-phosphogluconate dehydrogenase	↓
Glycogenesis	Stimulated by insulin and glucose	ND
	High-phosphorylation state (ratio of ATP to ADP)	ND
Glycogenolysis		ND
	Stimulated by catecholamines	ND
Lipogenesis	Stimulated by insulin	
	Acetyl-CoA carboxylase	
	High-phosphorylation state	
	Malate citrate shuttle	↓
Gluconeogenesis	Stimulated by epinephrine	
	Malate aspartate shuttle	↓
	Redox state	↑
	Phosphoenopyruvate carboxykinase	↓
	Pyruvate kinase	
Cholesterogenesis	HMG CoA reductase	
Ureogenesis	Carbamyl phosphate synthesis	↑, ↓
	ATP	ND
Citric acid cycle	All three shuttles	
	Phosphorylation state	↓
Lipolysis	Lipoprotein lipase	↓
Respiration	ADP influx into the mitochondria	↓
	Ca^{2+} flux	
	Shuttle activities	↓
	Substrate transporters	↓
Oxidative phosphorylation	ADP-ATP exchange	↓
	Ca^{2+} ion	
Protein synthesis	Accuracy of gene transcription	↓
	Availability of amino acids	↓
	ATP	↓

[a] ↑, increased as the animal ages; ↓, decreased as the animal ages; ND, no data.

As aging proceeds there is a rise in blood lipids coupled with a decrease in adipose tissue lipoprotein lipase. Adipocytes have a less competent lipid uptake system due to this decline in lipase activity. In normal aging animals the rates of cholesterol synthesis do not change; however, the uptake of this cholesterol as well as its oxidation and excretion declines. This has the result of an age-related increase in serum cholesterol levels. Genetics plays an important role in these age-related changes in serum lipids. Some genotypes are characterized by a sharper decline with age in lipid uptake processes than other genotypes. For example, those whose lipoprotein receptors are genetically aberrant will show a far earlier rise in serum lipids than those whose receptors are fully functional. Some may only have a decline in cholesterol uptake or triacylglyceride uptake, whereas others will have a decline in the uptake of both. Age-related declines in thyroid hormone production, thyroxine conversion to triiodothyronine, glucocorticoid release, and the insulin:glucagon ratio will have effects on fatty acid mobilization and oxidation. The results of this decline in hormone-stimulated lipolysis are observed as an age-related expansion of the fat stores. Although age has effects on fatty acid synthesis in rats and mice, these effects are minimal in humans consuming the typical Western diet. This is because this diet is relatively rich in fat, so the need for its synthesis is almost non-existent. Humans tend to use the dietary carbohydrate as their primary fuel and the surplus dietary fat is transported to the adipose tissue for storage. Hence, *de novo* fatty acid synthesis is negligible. In rats and mice this is not the usual situation. The typical rodent diet is low in fat. Most of the energy comes from carbohydrate and deaminated amino acids (those in excess of need for protein synthesis). In the young animal there is considerable protein synthesis, and with age there is a decline in this synthetic activity. With an age-related decline in protein synthesis there is an increased need to rid the body of amino groups, as the surplus amino acids are deaminated for use in gluconeogenesis and lipogenesis. This means that if the protein intake is not reduced to accommodate the decreased need for protein, there will be an increase in the activity of the urea cycle. Studies in aging rats have shown that dietary intake excess of energy and protein are associated with an age-related increase in urinary protein and renal disease that is preceded by first an increase then a fall in ureogenesis. Food restriction or protein restriction ameliorates these age-related changes in renal functions and urea synthesis.

All of these age-related changes in intermediary metabolism are linked together by age changes in mitochondrial oxidative phosphorylation. As discussed previously; age carries with it a progressive change (increase) in mitochondrial membrane saturation, a progressive loss in ATP synthetic efficiency, and an increase in free radical damage to mitochondrial DNA and its translation products. These progressive changes mean a progressive loss in the tight control of intermediary metabolism exerted by the concentration and flux of the adenine nucleotides. In turn then, one might expect to find progressive changes as described above in carbohydrate, lipid, and protein metabolism in addition to and in response to the progressive changes with age in the endocrine system and the central nervous system.

See also: Cell Death; Cholesterol and Cell Plasma Membranes; Endocrine Function and Dysfunction.

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Mid-Life and Later-Life Crises

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Glossary

Chronic Strain – Persistent or recurrent demand that requires behavioral, cognitive, or psychological readjustments over a prolonged time period.

Coping Resources – Personal and social characteristics upon which people may draw when managing crises or stressors.

Coping Strategy – Cognitive and/or behavioral effort to manage crises or chronic stressors that are perceived as distressing or exceeding one's ability to adapt.

Life Events – Objective changes in one's social roles, contexts, and relationships that require major behavioral readjustments within a relatively short time period.

Well-Being – A state that encompasses any or all of positive mood, good physical health, and general life satisfaction.

Introduction

Social gerontologists do not share a single conceptualization of midlife and later-life crises. Rather, different subdisciplines offer distinctive yet complementary perspectives. Developmental and life span psychologists conceptualize a crisis as a normal stage in the life course when an individual must resolve a developmental or psychosocial challenge. Sociologists and social epidemiologists, in contrast, broadly conceptualize crisis as a transition that deprives an individual of a meaningful role, status, or relationship and thus requires a restructuring of and adaptation to one's new environment. Such crises may be acute events or chronic stressors. Important mid- and later-life crises include divorce, widowhood, retirement and job loss, health problems, parental bereavement, grandparent–grandchild coresidence, and caregiving. These acute and chronic crises compromise the well-being of middle-aged and older adults because they may threaten one's self-concept, create secondary stressors and role conflicts, and indicate a failure to achieve one's earlier goals. The extent to which a crisis taxes one's well-being is contingent upon its timing, meaning, and social context. Both psychological and sociological perspectives share the assumption that crises often have unanticipated positive consequences; they may foster personal growth, an enhanced sense of self-efficacy, and the pursuit of meaningful new challenges and relationships. Empirical research on the causes and consequences of mid- and later-life crises is most persuasive when it is based on large-scale representative community samples, on longitudinal data that obtain pre-crisis measures of one's personal characteristics, and when a diverse array of physical, psychological, and social consequences of crises are considered.

Conceptual Issues: Defining Crises

Psychological Perspectives

Developmental psychologists and life span psychologists conceptualize a crisis as a stage in the life course when an individual must resolve a developmental or psychosocial challenge. Only when this crisis is resolved can the individual adapt successfully to the aging process. Robert Havighurst proposed that individuals must accomplish a set of age-defined developmental tasks in order to achieve successful adult development. For midlife persons, these challenges include asserting oneself, while persons in their 50s through early 60s are charged with creating a new lifestyle. At age 60 and beyond, developmental tasks include deciding whether and how to disengage from social roles such as paid employment. The failure to accomplish such tasks is indicative of a crisis or poor psychological adjustment.

Similarly, Erik Erikson proposed that as an individual ages, he or she passes through eight psychosocial crisis stages. Successful adult development is contingent upon the sequential resolution of each crisis. The distinctive challenge of midlife is to resolve the conflict between generativity versus stagnation. A midlife adult is expected to avoid the lure of self-absorption and to instead become generative – working to preserve values and opportunities that will benefit succeeding generations. Older adults, in contrast, face the challenge of ego integrity versus despair; this entails resolving conflicted feelings about the past, adapting to the changes associated with the aging process, and accepting the inevitability of death.

More recently, social scientists have debated whether a psychological midlife crisis exists, and if so, what such a crisis comprises and what the consequences are for emotional well-being. Theoretical writings propose that at midlife, adults may reach a psychological turning point where they evaluate their past accomplishments and shortcomings, give up an unfulfilled life dream, or carve out a new life plan for themselves as they recognize their own personal finitude. Empirical research finds little evidence that adults undergo a midlife crisis. Estimates vary, but no more than 10 to 25% of older adults report that they have experienced a midlife crisis. Rather, most adults describe their 20s and 30s as the years when they grappled with crises including economic strain, difficult choices about work, marriage, and childbearing, and skepticism about the rewards promised by the Protestant work ethic.

One of the most important contributions of midlife crisis research is the recognition that a crisis need not be defined in terms of objective life conditions, nor must it necessarily refer to negative experiences. Qualitative research reveals that adults typically describe their own midlife crises as psychological turning points, such as learning something new about oneself or a loved one. Older adults who recall having experienced a crisis earlier in life consistently describe the event as having had unanticipated positive consequences. Although an experience might have been distressing at the time of its occurrence, in retrospect people believe that they enjoyed personal growth or enhanced self-efficacy as a result.

Sociological Perspectives on Crises

Early Influences While psychological perspectives on mid- and later-life crises typically conceptualize a crisis as a normal and anticipated challenge of the aging process, sociological perspectives on crises conceptualize such events or conditions as nonnormative, unexpected, and necessitating adjustment and adaptation. Sociological research and theory on life crises developed out of early animal and biological research on stress. Research by W. B. Cannon concluded that emotionally distressing experiences could be adaptive because they help animals to cope. For instance, fear triggers heightened adrenal gland activity, which in turn gives animals the energy necessary to fight or flee from a threat or aggressor. Adolph Meyer proposed that normative (and even positive) life transitions, such as marrying or having a child, are potentially distressing – both psychologically and physically – and require subsequent adjustment. Perhaps the most influential early research on stress was conducted by Hans Selye; his experiments with animals revealed that a diverse range of physical stressors could trigger a similar set of physiological responses, including alarm, resistance, and exhaustion.

Reflecting the early biological emphasis on stress, sociological research seldom uses the term 'crisis', and instead uses the terms 'life stress' or 'stressor' to capture an event or transition that requires readjustment. The main objective of early empirical sociological research on crises included identifying and measuring the potentially harmful consequences of a broad array of stressors. The first comprehensive measure of life stress, the Social Readjustment Rating Scale (SRSS), devised by social scientists Thomas H. Holmes and Richard H. Rahe, included a list of 43 events that were believed to be distressing and thus to require readjustment. Even experiences or transitions that are generally regarded positively, such as vacations, were considered potentially stressful, although the intensity of this distress was far less than for events such as the death of a loved one. The SRSS has

been criticized on the grounds that it presumes that a given event is equally stressful for all individuals, regardless of one's role history, coping resources, or subjective appraisal of the event. However, the idea that crises could be measured and that their psychological consequences could be evaluated empirically set the groundwork for empirical research on mid- and later-life crises. Taken together, early research on stress generated several important conclusions that underlie contemporary research and theory: crises affect physical and emotional well-being by overwhelming one's coping abilities and resources; individuals are variable in both how and the extent to which they respond to diverse stressors; and even expected, normative life transitions can have harmful consequences.

Contemporary Perspectives Over the past three decades, sociological research on crises has grown from a focus on discrete life events only to a broader view that conceptualizes crises as also encompassing chronic stressors and daily hassles. Some researchers also would include in this list 'non-events', or the nonoccurrence of events that were desired or anticipated. Life events are objective life changes or transitions that typically require readjustment. Events may disrupt one's regular activities, roles, and relationships and also may threaten one's emotional, physical, or economic well-being. Events can vary widely in their severity. Traumas are a particularly distressing class of life events. A trauma is a crisis that is outside the range of usual human experience and would be markedly distressing to almost anyone. Traumas are relatively rare, however, and are not the primary focus of most empirical research. Rather, most research on life events – particularly among older adults – focuses on role losses, including retirement, widowhood, divorce, or even the loss of one's physical capacity to live independently. Role loss is considered a crisis because it excludes older adults from significant social participation and thus devalues them.

Crises can transcend an individual's own personal experiences and may encompass the experiences of one's significant others. Network events refer to crises that are experienced by members of one's social network and that also have direct personal consequences. For instance, a sibling's widowhood experience may be distressing to an older adult and may require readjustment. Likewise, mid- and later-life crises need not be acute events; they may be ongoing chronic experiences. Chronic stressors are enduring, persistent difficulties, such as physical disabilities, poverty, or marital difficulties that tax one's personal resources. A less severe variant of chronic stressors, hassles, are minor events that require small behavioral adjustments in the course of a day, such as transportation difficulties or inclement weather. For older adults, particularly those with cognitive or physical impairments, even daily hassles may be perceived as crises that require adjustment.

Methodological Issues in Studying Crises

Social gerontologists are interested primarily in how, why, and to what end crises affect the well-being of midlife and older adults. Identifying the personal consequences of both acute and chronic crises poses several methodological challenges for researchers. The most persuasive and rigorous research is based on large, nationally representative surveys, rather than clinical samples, or non-representative samples limited to persons who have experienced a specific crisis. Longitudinal data that include personal information both prior to and following the purported crisis are necessary. Moreover, scholars ideally will focus on multiple outcomes in their research; a focus on a single outcome, such as depression, may conceal a much broader range of consequences. Finally, studies should have sufficient numbers of subjects from diverse age groups in order to evaluate whether and how crises affect adults at different life course stages.

Population-Based Studies

Studies of life crises that focus on patient, clinical, or self-help samples only cannot be generalized to broader populations. By definition, these older adults are already seeking help, and findings from such studies may overstate the negative consequences of a crisis. For instance, widows who are seeking psychiatric treatment presumably are more symptomatic than their bereaved peers not seeking help. Population-based samples, in contrast, allow researchers to compare those persons who have undergone a crisis with their peers who have not; in doing so, researchers can identify the causes and personal consequences of a crisis. Large community samples enable researchers to examine subgroup variation even among those who have experienced an identical crisis. Researchers can examine whether the consequences of a crisis vary based on the meaning, timing, or expectedness of such an experience.

Longitudinal Data

Longitudinal data are superior to cross-sectional data for studying the consequences of life crises, because they enable researchers to identify the factors that gave rise both to the crisis and to one's subsequent

adjustment. Although some late-life crises may occur randomly and are unrelated to the personal characteristics of their target (e.g., losing one's home in a natural disaster), most mid- and later-life crises are selective and reflect one's prior experiences and personal characteristics. Most discrete events or crises take time to come to fruition and often occur after a long period of chronic stress. For example, forced retirement may occur after months of workplace strife and uncertainty. Longitudinal data also allow researchers to examine changes in well-being that occur during the time period prior to and after the crisis of interest. Longitudinal data allow researchers to track one's role history prior to the crisis. In some cases, a role loss may not be particularly distressing if the role was stressful or problematic. For instance, widowhood may come as a relief rather than a crisis to a frail older person who has been providing intensive care to a dying spouse with severe dementia.

Multiple Outcomes

Most research on mid- and later-life crises focuses on psychological well-being; however, social gerontologists may develop a richer understanding of how older adults adjust to crises by considering a fuller range of psychological, physical, social, and behavioral outcomes, including social engagement and participation, social support from family and friends, physical health, strategies for managing daily activities, and personal growth in the face of crisis. Moreover, commonly used global measures of adjustment – such as depression – may mask more specific adjustments to crisis. For example, depression scales are composed of subscales including depressed affect, motivational loss, cognitive evaluations, and somatic complaints. Older bereaved spouses with clinical depression may not exhibit a dysphoric or sad mood, but instead may show elevated somatic concerns and irritability. Research focusing only on one overarching depression scale may mask these important distinctions.

A focus on multiple outcomes also enables researchers to identify important subgroup differences in how individuals respond to crises. To the extent that different groups have distinctive reactions following a crisis, studying a single outcome may conceal meaningful group comparisons. For instance, age-related emotional and cognitive changes affect the ways that midlife and older adults adjust psychologically to a crisis. Compared to younger adults, older adults have a greater capacity to manage or regulate their emotional states; they report less extreme levels of both positive and negative affect and less variability in their emotional responses to crisis. However, they may show elevated somatic or physical reactions. Studies that focus on a single psychological outcome would not reveal the physical consequences of the crisis.

Why and How Do Crises Matter?

Crises, particularly role losses, have long been recognized as an important influence on the well-being of older adults. In the classic work *Personal Adjustment in Old Age*, Ruth Shonle Cavan and colleagues set forth the idea that activity is an important source of well-being among older adults, thus the loss of roles is potentially distressing. While early theories of aging (e.g., activity theory and disengagement theory) equated role loss with reduced activity and, consequently, social withdrawal, more recent perspectives suggest that crises (particularly role losses) are distressing because they threaten one's identity, create secondary stressors, indicate a failure to comply with personally held goals and pervasive social expectations, or violate a socially and institutionally sanctioned timeline to which one should adhere.

Identity Threat

Crises can threaten individuals' self-concepts and thus make them more susceptible to psychological distress. Because an individual's identity and sense of self are based largely on social attachments and are derived from social interactions, both chronic and acute stressors that disrupt or damage relationships with significant others – such as divorce, widowhood, job loss, or the onset of disability or cognitive decline – can have harmful consequences.

The consequences of such crises are most acute when they threaten identities that individuals value highly and from which they derive a sense of meaning, purpose, and direction. Identity-threatening crises in highly salient domains have a greater impact on psychological well-being than those in less salient or personally important domains. For instance, job loss is most disruptive for men who highly valued the role of breadwinner, whereas widowhood is most distressing for those persons who were in very close, dependent marriages and who based their personal identity on their role of spouse.

Secondary Stressors and Role Conflict

Crises may threaten older adults' well-being because they often give rise to secondary stressors that, in turn, compromise one's ability to cope. Secondary stressors are both chronic and acute stressors that are triggered

by the primary stressor. For example, a severe chronic illness (or providing care to a spouse with a severe chronic illness) could precipitate a job loss, which, in turn, might entail economic hardship. For older women, in particular, the loss of a spouse often leads to social isolation, economic difficulties, or relocation to a less desirable home. Marital disruption also may strain one's relationship with adult children, who may not fully accept the termination of their parents' marriage or who may perceive their newly single parent as incapable of maintaining his or her independence.

Crises and the secondary stressors that result from them may also give rise to role conflict or overload. Although the loss of key roles is a threat to one's identity, the acquisition (particularly the unwanted acquisition) of multiple social roles may threaten one's emotional well-being. Older adults may not have the time, energy, or social and economic resources necessary for managing the responsibilities associated with each of their social roles. When the demands of one role, such as spousal caregiver, become especially taxing, an older adult may be less well equipped to perform other important social roles (such as worker or parent) and may experience psychological distress or physical exhaustion.

Failure to Achieve Goals and Expectations

At midlife and later-life, individuals reflect on their past and evaluate their successes and disappointments. This retrospective process of life evaluation often engenders regrets over missed opportunities and unattained goals. Empirical research reveals marked gender differences in the sources of regret, and these differences reflect distinctive opportunities and constraints facing men and women in their young adult years. Older women tend to express regrets over their educational and career pursuits; most wish that they had received more education and had pursued careers that meshed with their interests and intellectual capacities. Men, in contrast, are more likely to report regrets over their decision to give priority to work over family. Regrets over missed opportunities often are triggered or exacerbated by a life crisis. After divorce, women who have devoted their energies to nurturing their husbands and children may regret not having channeled more of their efforts to personal pursuits and accomplishments. Upon unwanted job loss or a disability leave from work, older men may recognize that they sacrificed family relationships for a career that was ultimately unsatisfying.

Off-time or Premature Crises

Although early research on crises presumed that an event is uniformly distressing, regardless of when and whom it strikes, more recent scholarship recognizes that the impact of a crisis is contingent upon its timing. Because most individuals try to adhere to culturally and institutionally endorsed time tables, events that occur 'off-time' are more difficult to cope with than those that occur 'on-time.' On-time events happen at the normative age for a given transition, whereas off-time transitions occur either earlier or later than expected or desired. Off-time transitions are considered particularly distressing because individuals who experience them are less prepared and are less likely to have peers who share their experience. Consequently, they may not have the social, instrumental, or institutional support necessary to weather such a transition. For example, older women have been found to cope with widowhood better than midlife women because spousal loss is a much more common event for older women, who may turn to their widowed peers for guidance and support.

Specific Mid- and Later-Life Crises

Marital Disruption: Divorce and Widowhood

Marital disruption is one of the most common crises experienced by older adults, particularly older women. Because men die younger than women, women are much more likely than men to be widowed at mid- and later-life. Although men and women are equally likely to divorce, midlife and older women are more apt than their male peers to remain divorced (or widowed) because they have limited prospects for remarrying, due to the imbalanced gender ratio and men's preference for younger wives. Among Americans age 55 and older, just 50% of women but 74% of men are currently married, as shown in **Figures 1** and **2**.

Widowhood and divorce are considered among the most disruptive life crises, yet recent empirical research indicates that mid- and late-life marital dissolution is not uniformly distressing. The personal consequences vary widely and are contingent upon the time lapsed since marital disruption, the nature and quality of the lost relationship and the dissolution process, and the number, type, and intensity of secondary stressors that follow the marital dissolution.

The negative consequences of marital dissolution decrease over time. Although many older bereaved persons experience elevated anxiety and depressive symptoms in the first 12 to 18 months following the loss, these symptoms eventually return to predissolution levels. In the longer term following dissolution, widowed and divorced persons – particularly women – experience personal growth and discover inner strengths and abilities.

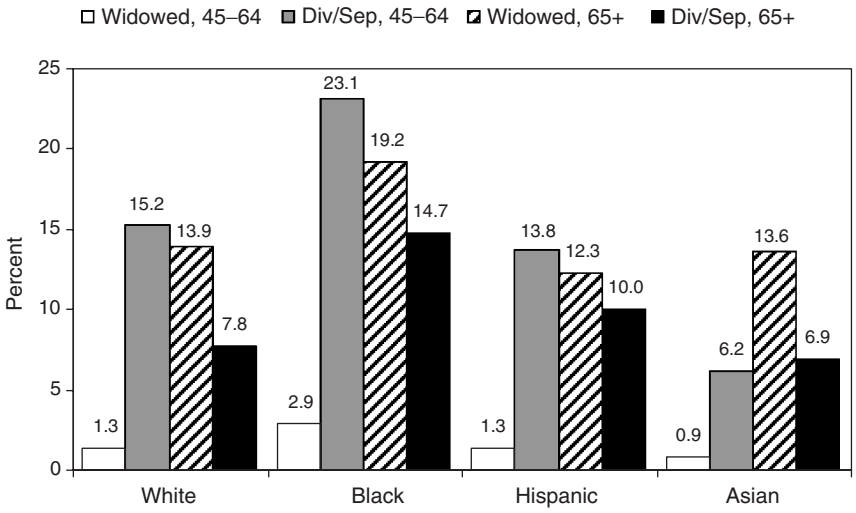

Figure 1 Percent of men age 45 years and older who were currently widowed or divorced/separated by age and race: 2003. From the US Census Bureau, Current Population Survey Reports, March 2003.

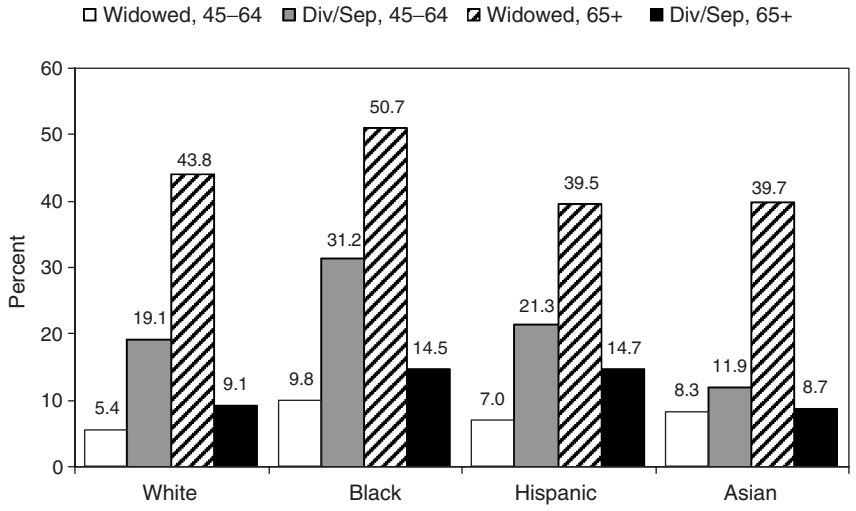

Figure 2 Percent of women age 45 years and older who were currently widowed or divorced/separated by age and race: 2003. From the US Census Bureau, Current Population Survey Reports, March 2003.

The short-term emotional consequences of marital dissolution are closely tied to the nature of the former marital relationship and the context in which the dissolution occurred. Divorces that dissolve a marriage to an unfaithful spouse are associated with subsequent increases in psychological health. The extent to which older bereaved persons adjust successfully to the loss of a spouse is contingent upon the quality of the late marital relationship, their level of dependence on their late spouse, and the extent to which the spouse's dying process was marked by physical pain, poor-quality medical care, and interpersonal difficulties. A purported crisis such as marital dissolution may have beneficial implications for the survivor when it brings an end to severe chronic strains.

Marital dissolution may trigger secondary stressors that cause psychological, physical, and financial distress. Women typically suffer economic hardship when a relationship ends, whereas men face challenges in maintaining a household and establishing supportive emotional relationships. The personal implications of these secondary stressors are most acute during the first year or two following the marital transition. The extent to which secondary stressors create distress for older adults also varies by sociohistorical context. Current cohorts of older women were highly dependent on their spouses for economic

security, whereas current cohorts of older men were dependent on their wives for emotional support. As the boundaries between traditional male and female gender roles erode, future cohorts of widowed and divorced older adults may be better equipped to manage the secondary strains associated with marital dissolution.

Employment Transitions: Unemployment and Retirement

The retirement experience has changed dramatically over the past half-century. Whereas retirement was largely a man's experience in earlier decades, retirement is now an experience of both men and women. Current cohorts of older women are more likely than prior generations to have worked for pay and thus are more likely to retire, as shown in **Figure 3**. Consequently, married couples must adjust to both spouses' retirements, rather than just the husband's; this raises the challenge of synchronizing spouses' career exits.

Retirement today is a process rather than a discrete event. Rather than making the clear-cut transition from worker to retiree, midlife and older adults are following diverse pathways to retirement. Some workers may make the gradual transition from full-time worker to part-time worker to retiree, while others will leave their career jobs for a bridge job before exiting the labor force. Others may retire completely, only to re-enter the labor market due to economic need. Although anticipated retirement is generally perceived as a desirable life transition, other late-life work transitions – such as forced retirement, lay-offs, or unwanted moves to less challenging or prestigious jobs – are perceived as crises.

The personal consequences of workplace transitions are contingent upon the quality and nature of one's former job and postretirement activities. In general, unwanted job loss is a risk factor for major depression, alcohol abuse, and physical health declines. However, the involuntary loss of a job that was highly stressful is not associated with adverse mental health outcomes. Similarly, retirees typically show lower levels of anxiety and higher levels of positive affect than their employed peers, yet some also experience a lower level of perceived control, reflecting the unstructured nature of their postretirement daily activities. At least some of the purported negative consequences of job loss are due to selection characteristics; job loss often is a consequence of prior physical and emotional health problems.

Health Crises and Disability

Chronic illnesses affecting older adults and, to a lesser degree, middle-aged persons are the main source of disability and physical impairment. The leading causes of death to older adults today – heart disease and cancer – are chronic illness that may persist for long time periods and that impair daily well-being and functioning (see **Figures 4** and **5**). Functional impairment, in turn, creates chronic strain and heightens one's dependence on others. Chronic illnesses reduce both actual life span and healthy life span, or the number of years that one enjoys good health and high levels of physical functioning.

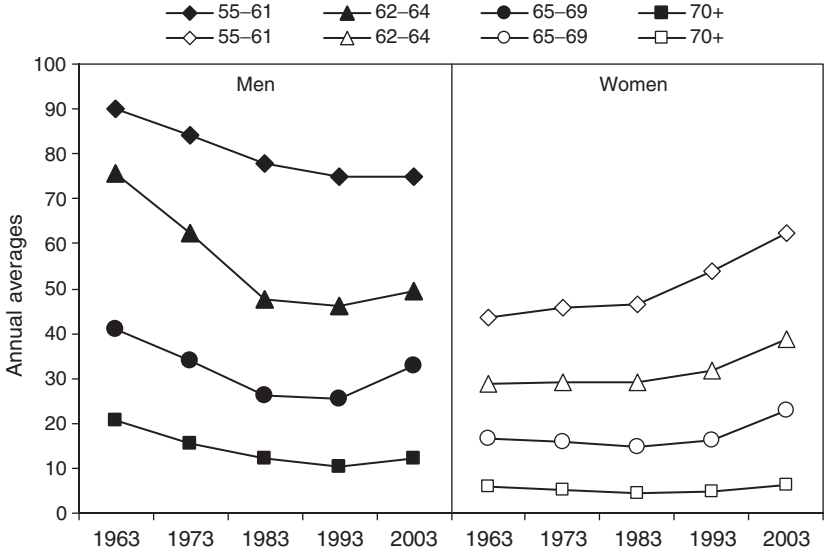

Figure 3 Labor force participation rates of men and women age 55 and older: annual averages, selected years, 1963–2003. From Federal Interagency Forum on Aging-Related Statistics, "Older Americans 2004: Key Indicators of Well-Being."

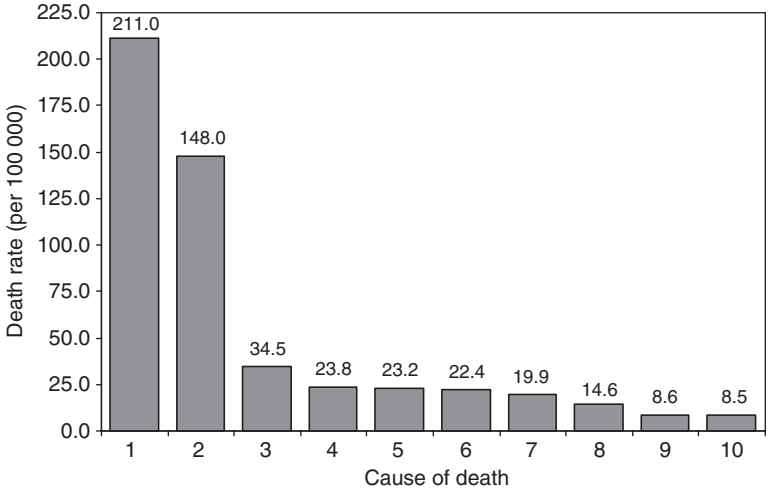

Figure 4 Death rates (per 100 000) for the 10 leading causes of death at midlife (45–64 years): United States, 2003. Note: 1, malignant neoplasms; 2, diseases of heart; 3, accidents; 4, diabetes mellitus; 5, cerebrovascular diseases; 6, chronic lower respiratory diseases; 7, chronic liver diseases and cirrhosis; 8, intentional self-harm (suicide); 9, HIV/AIDS; 10, septicemia. From National Center for Health Statistics, National Vital Statistics Reports, Vol. 53, No. 15.

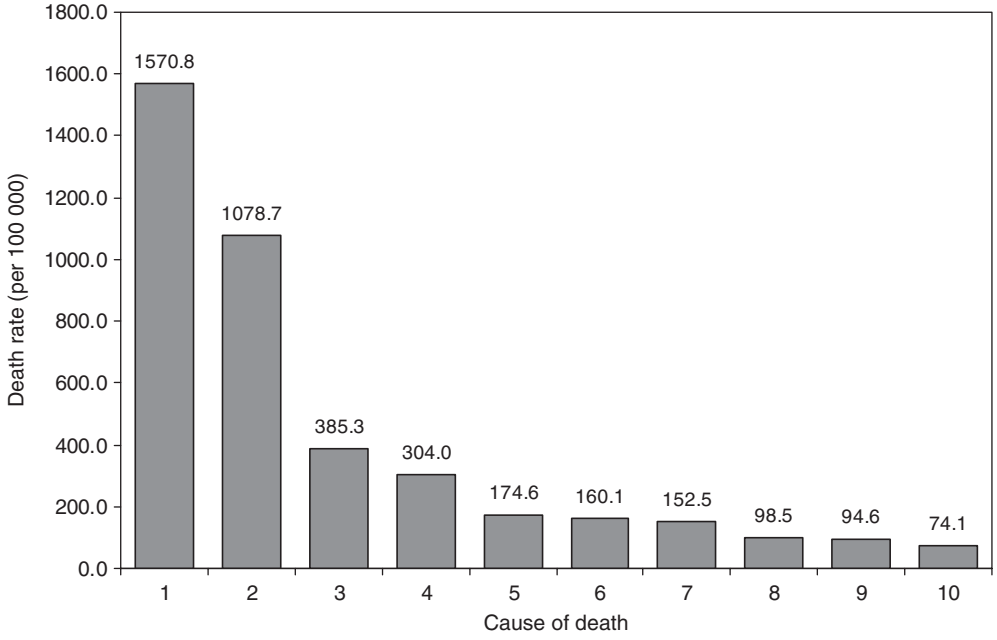

Figure 5 Death rates (per 100 000) for the 10 leading causes of death in late life (65 years and older): United States, 2003. Note: 1, diseases of heart; 2, malignant neoplasms; 3, cerebrovascular diseases; 4, chronic lower respiratory diseases; 5, Alzheimer's disease; 6, influenza and pneumonia; 7, diabetes mellitus; 8, nephritis, nephrotic syndrome, and nephrosis; 9, accidents; 10, septicemia. From National Center for Health Statistics, National Vital Statistics Reports, Vol. 53, No. 15.

Disability is both the cause and consequence of other acute and chronic stressors. Disability and health problems are among the most powerful predictors of changes in one's labor force participation. Health problems also trigger economic hardships. Direct expenditures on health care typically increase with the severity and duration of one's illness. Health problems also have indirect costs, in that they force older adults to either exit the labor force or cut back on their paid employment. Similarly, caregivers to ill family members may cut back on work or exit the labor force in order to care for their ailing loved one.

Disability may force adults to limit their social interactions and activities; persons with impaired mobility, chronic pain, and intrusive symptoms and who must participate in intensive treatment regimens are

susceptible to social isolation. Disabling and life-threatening physical health conditions often trigger mental health problems, including depression, anxiety, and anger, although social support may buffer the adverse impacts of disability.

Other Bereavements

Much is known about spousal bereavement in mid- and later-life, yet relatively little scholarly attention is paid to other deaths to significant others. Given steady increases in life expectancy over the past half-century, particularly among the oldest-old (i.e., persons age 85 and older), midlife and older adults are more likely than past generations to experience the loss of a very aged parent. Parents who die very late in life are likely to have experienced a chronic and debilitating illness and an accompanying period of physical or cognitive impairment. Adult children often are the primary source of instrumental and financial assistance to oldest-old persons; consequently, the death of an aged parent may indicate a termination of difficult caregiving activities and a relief from chronic strain and overload.

Yet parental death can be a highly distressing crisis, even for middle-aged and older adult children. Parental death may trigger identity changes, a heightened realization of one's own mortality, and a re-evaluation of one's priorities and personal relationships. Parental death may also create strain for one's marital relationship; some bereaved children report heightened levels of marital conflicts and dissatisfaction with the amount of emotional support they receive from their spouse.

Network Events: Child Problems and Grandchild Coresidence

The problems experienced by one's adult children may have a profound impact on the quality of life among midlife and older adults. Adult children with relatively minor problems, such as unstable employment or a troubled marriage, may coreside (temporarily) with a parent. Parent–child coresidence is not necessarily distressing; most parents express high levels of satisfaction when they coreside with adult children, particularly when the parent–child relationship is warm and close. However, when children's problems are protracted or severe and the children are financially dependent or unable to maintain an independent residence, both parental satisfaction and intergenerational relationship quality suffer.

When adult children's problems are severe or protracted, middle-aged and older adults often must coreside with their grandchildren and assume either custodial or coparenting responsibilities. In 2002, nearly 6 million children under age 18 lived with their grandparents. Reasons for grandparent–grandchild coresidence include a child's divorce, incarceration, financial problems, drug use, severe illness, psychological problems, teenage pregnancy, and inability to care for their child (i.e., the older adult's grandchild).

Coresidence with grandchildren – and custodial grandparenthood, in particular – is often an unanticipated and involuntary transition that places older adults at risk of increased economic burden and elevated levels of psychological distress, insomnia, and hypertension. The extent to which grandparent–grandchild coresidence creates distress varies widely across racial and ethnic groups, however. Black women report greater satisfaction than their White peers, reflecting cultural differences in expectations for family relationships and roles.

Caregiving Responsibilities

Midlife adults have been dubbed the 'sandwich generation', as they face the competing demands of providing emotional, instrumental, and financial support to both adult children and their aging parents. Older adults, particularly older women, often are charged with providing care to chronically ill spouses and, on occasion, siblings, friends, and other relatives. Although intensive caregiving responsibilities often tax the coping resources of midlife and older adults, recent research shows that the caregiving experience is not uniformly distressing and in some cases may provide an important source of purpose and identity.

Most research shows that caring for an ill or disabled person is associated with declines in physical and mental health. Yet the health impact is contingent upon role context and coping resources. Personal characteristics including high psychological well-being, good physical health, religiosity, multiple role involvements, and social integration buffer the psychological strains of caregiving. Moreover, recent research documents the beneficial psychological implications of caregiving. Caregiving is positively related to mastery, self-esteem, and the belief that one matters to loved ones.

Coping with Mid- and Later-Life Crises

Coping Resources

Over the past two decades, a vast amount of research has explored the processes by which midlife and older adults cope with crises. Coping typically refers to both one's coping resources and coping strategies. Coping resources are personal and social resources that people draw upon when dealing with crises. Personal coping resources include individual-level attributes that

enhance (or limit) one's ability to manage stress, such as education, self-esteem, and a sense of control or mastery over one's life. One's social resources typically refer to social support, or the emotional, instrumental, or informational assistance received from significant others, including family members, friends, neighbors, or co-workers. The perception that support is available is a much more powerful influence on psychological adjustment to crisis than is the actual receipt or availability of such support. More generally, coping resources are believed to shape both the coping strategy that one undertakes and the potential effectiveness of that strategy.

Coping Strategies

Coping strategies are behavioral and cognitive tactics used to manage crises, conditions, and demands that are appraised as distressing. An important development in coping research was the creation of Robert Folkman and Susan Lazarus' Ways of Coping scale. This scale was devised to assess the extent to which one uses one of two general types of coping. Problem-focused coping is directed at problem solving or taking action to change the source of the stress. Emotion-focused coping, in contrast, focuses on reducing or managing the emotional distress that results from the crisis. Some emotion-focused coping strategies include wishful thinking, distancing, avoidance, and positive reappraisal. The effectiveness of any particular coping strategy varies according to the situation, and there is not one generally accepted way for older adults to cope with stress. Moreover, most crises warrant both types of coping.

Problem-focused strategies are typically invoked when constructive action can be taken, whereas emotion-focused coping is used when people feel that the situation cannot change and must be endured. In general, problem-focused coping strategies are considered more effective for managing crises than emotion-focused tactics. Persons who use active coping strategies typically view themselves as in control, hold positive self-views, and adopt a proactive, optimistic and self-reliant approach to managing life stressors. In contrast, those who rely on emotion-focused coping strategies, including self-blame, avoidance, or even the use of drugs or alcohol, cope less well than those who adopt active strategies, such as seeking social support. However, for older adults, problem-focused coping is not always effective when a loss is irrevocable. Rather, emotion-focused strategies such as the positive reappraisal of a permanent condition or situation are associated with enhanced mental health.

Resilience in the Face of Crisis

One of the most consistent findings to emerge from empirical work on crisis is that the negative psychological and interpersonal consequences of most stressful transitions, such as widowhood, parental bereavement, or caregiving, are short-lived, and most older adults eventually reach levels of psychological and social well-being that are on a par with their precrisis levels. Moreover, most healthy older adults find substitutes for lost roles, activities, and relationships; for example, healthy retired persons are more likely than others to perform volunteer work, and bereaved spouses often develop new skills and forge new (or renew old) interpersonal relationships. These empirical findings mesh with a core assumption of both psychological and sociological perspectives on crises: personal growth and satisfaction may result from the resolution of a crisis. In Erik Erikson's stage theory, when an adult resolves each of the eight psychosocial crises, he or she may emerge with a new skill or sense of confidence that can be incorporated into his or her coping skills. Likewise, sociological perspectives on crises hold that events or circumstances involving adverse change can have positive effects on coping skills and world views, as individuals increasingly view themselves as efficacious and capable of managing crisis.

Challenges and Future Directions

The Distinctive Experience of Aging Baby Boomers

Most research and theory on mid- and later-life crises has focused on current cohorts of older adults who came of age in the early and mid-twentieth century; it is not clear whether similar patterns will be found among the large cohort of aging Baby Boomers, born between 1946 and 1964. The Baby Boomer cohort is more ethnically and racially diverse than past cohorts of older adults; however, surprisingly little research explores racial or ethnic differences in older adults' exposure and response to crisis. This reflects the fact that most large-scale sample surveys include inadequate numbers of non-White elders. Consequently, researchers have little understanding of how a crisis can vary in its causes, consequences, and cultural meaning across ethnic groups and how sociopolitical and historical contexts of ethnic groups shape their late-life experiences. Baby Boomers also are more highly educated than past cohorts of older adults and are far less likely to adhere to gender-typed social roles in the family and the economy. They are more likely to divorce and have fewer children than prior generations, thus they may turn to a more diverse set of significant others to cope with crises, including

siblings, friends, unmarried romantic partners, or gay and lesbian partners. Future research should investigate the types, frequencies, and responses to mid- and later-life crises evidenced among the large and diverse Boomer cohort.

The Blurring of Crisis Boundaries

In future cohorts of midlife and older adults, crises will increasingly be experienced as protracted processes rather than events. Late-life deaths today occur largely due to chronic illness, and life-sustaining technologies mean that terminally ill adults, often with cognitive impairment and limited functioning, will stay alive in a compromised state long before they die. Consequently, spousal and parental loss may be a slow process rather than an acute transition. Similarly, retirement is now a gradual process rather than a discrete event, as older adults transition into part-time or self-employed work prior to a complete exit from the labor market. Although older adults have more time to prepare for and adjust to important crisis-like transitions, the protracted experience may overwhelm their personal, social, and financial resources.

Moving beyond the Individual

Research and theory on mid- and later-life crises focuses overwhelmingly on the individual. Significant others are conceptualized as a source of support for managing a crisis, yet very few studies explicitly recognize that crises often strike a dyad or social group, and individuals must work together to adjust to such a crisis. For example, bereaved older spouses must adapt along with their adult children, who have lost a parent. Older workers' retirement decisions typically are made in coordination with their spouse, just as an individual's decision to provide care for an ailing parent often is made in tandem with his or her siblings. Crises do not occur in social isolation; future studies should acknowledge the inherently social and interpersonal nature of both the onset of mid- and later-life crises and adults' subsequent adaptation.

See also: Adaptation; Bereavement and Loss; Caregiving and Caring; Death and Dying; Demography; Gender Roles; Grandparenthood; Life Course; Life Events; Life Review; Life Satisfaction; Life Span Theory; Marriage and Divorce; Mental Health; Psychological Well-Being; Retirement; Theories of Aging: Psychology; Theories of Aging: Social; Widowhood and Widowerhood; Work and Employment: Individual.

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Migration

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Glossary

Interstate Migration – Per the US census, residence in another state 5 years before the census is taken.

Retirement Migration – Interstate migration of persons aged 60 and over, some of whom may have become employed since moving.

Introduction

Retirement migration is one aspect of a broader cultural happening that is very old. Winter palaces, the social season in the capital city, mineral springs, spas, and Italian villas have for centuries been part of the lifestyle of the European elite. Vacationing, seasonal migration, and retirement resettlement to a more healthful climate offering leisurely lifestyles are becoming widespread phenomena in the United States, but only after the development of a substantial middle class and transportation technology that makes travel to distant places possible and affordable. Thus, these activities have become common only in this century. Although the individual community histories of retirement settlement may extend back to the 1920s and 1930s in some places, retirement migration became more than a novelty only after World War II.

In each decade between 1960 and 2000, both the number of Americans and the number of older Americans have increased; the latter increased faster. Not surprisingly, the number of interstate migrants also grew in each decade. The proportion who moved in each 5-year period preceding the census, however, remained nearly constant, both for the population over age 5 (at about 9%) and the population over age 60 (at about 4.5%). A trend that reaches back for five censuses is very stable. Local mobility declined during this period for both categories.

Retirement migration is an alternative lifestyle. Most Americans over age 60 have not moved in any census migration period. Roughly three-quarters are living at the same address as earlier; only one in ten has moved across country or state lines. Most tend to stay put when they retire (*see* Retirement).

Conceptual Issues

Lifestyles and Place Ties

Asking why most people do not move is one way of ascertaining why some people do move. People are tied to their environments by investments in their property, by the many community contexts in which they find meaning, by friends and family, by their past experiences, and by lifestyles that weave these strands together into patterns of satisfying activity. Any lifestyle requires a unique combination of environmental resources, and a retirement lifestyle is no exception to this rule. It is the combination of place ties, person ties, and resources that is the key to understanding what is behind a retirement move. The retirees who are most likely to relocate are those who have the fewest moorings and those whose desired retirement lifestyles are not compatible with their present community, neighborhood, and housing environments.

Person Ties

Lifestyle-motivated moves tend to be place centered. When migration researchers focus on particular popular retirement destinations, they often find amenity-seeking migrants there. Person-centered motivations for moving are equally important.

Resources

If place and person ties often go undifferentiated when motives are assessed or inferred, it is equally true that place ties and resources are often confused. Retirees vary considerably in their possession of the resources needed to relocate – particularly their economic, health, and psychic resources. Psychic resources refer to the inner strength and freedom needed to take the risks involved in moving. Strong community moorings can reduce these psychic resources by lessening the ability to mount the effort to move even if income and health resources are abundant.

Search Space

When the members of a retired household are considering a move and begin looking for housing, geographers define the territory in which the couple will search for a new residence as a search space. The search space of the couple is defined by their previously acquired knowledge. This knowledge, of course, is informed by earlier visits, discussions with migrants and travelers, and reading. Rarely does someone move to a place completely unknown to that person, unless the move was forced. The primary

reason that people choose new locations where they have vacationed and visited is because they have gained the necessary knowledge base to make that choice.

Because the search space is conditioned by knowledge requirements and motivational factors, the size of the target area will vary from retiree to retiree. Migration flows, therefore, are not narrowly targeted because of varying amounts of search space.

Migration Motivation

Older migrants, like people in general, come in many types. The research literature tends to classify them into two major categories: dependency migrants and amenity migrants. Dependency migrants are typically forced to move due to deterioration of health or financial resources or the death of a spouse. Amenity migrants are looking for settings that will afford a new and better lifestyle. Communities located on or near lakes, beaches, and mountains and those in temperate, tropical, or desert climates have an advantage in attracting this type of migrant, who tends to be recently retired and therefore younger, usually married, and economically better off than many other retirees. Interstate migration streams to the Sunbelt are laden with amenity migrants.

Life Course Models

One popular way of combining an analysis of place and person ties and resources is to examine the way that migration motivation tends to change during the retirement years. Litwak and Longino argued that long-distance movers during the retirement life course tend to fall into three categories. The first are recently retired amenity-seeking migrants. The pressure for the second type of move, however, occurs when people develop a disability that makes it difficult to carry out everyday household tasks, a situation often compounded by widowhood. Limited kin resources is the motive for the third basic type of move, from more or less exclusive care by kin to institutional care. Most movers that fit the third type are local, not long-distance, movers (*see* Life Course).

Migration Decision Models

The origins and destinations of the migrant have attractions and repulsions ('pushes' and 'pulls'). In migration research there is a strong tendency to attempt to infer the motivation of the migrant by studying the characteristics of the places they leave and the places to which they move. For example, in aggregate, origins have lower average winter temperatures and higher costs of living than destinations; both factors are pushes. Rural areas in the southeast United States that have consistently attracted older migrants tend to have mild climates, to be growing economically, and to have lower taxes. They tend to be coastal or mountainous and many are adjacent to metropolitan areas.

Migration decisions may be triggered by push and pull factors such as climate, traffic and street crime, or cost of living and facilitated by endogenous filters such as personal resources or the housing market. There are also feedback loops. People who do not decide to move, or who cannot successfully choose a destination, may adjust to their present location through various mechanisms in order to avoid feeling trapped there. Furthermore, over time, migration outcomes that initially are improvements can generate new pushes and pulls that may eventually trigger another move. Daydreams about moving that precede the actual process and information about push-pull factors are obviously also important.

Place Identity Models

Some migrants who never put down roots remain emotionally tied to their former communities. Others have problems with the transition from being a vacationer to being a permanent resident after they arrive in their destination communities. Considering these issues with a social psychological approach has brought a new dimension to the understanding of migration and migrants.

Migration

Patterns of Migration in the United States

State Flows and Streams One of the defining characteristics of interstate retirement migration is that the migrants coming from many states are concentrated in only a few destinations, a result of highly focused flows into certain states. In 2000, over half of older migrants, 54% (compared to 56% in 1990), arrived in just 10 states. Florida dominates the scene, having attracted from one-fifth to one-quarter of all interstate migrants over 60 in all five censuses from 1960 to 2000.

A new phenomenon occurred in 1990. There was a small, gradual decrease in the proportion of migrants received by the major destination states, with a gentle spreading out of the flows (as compared with earlier migration periods). As **Table 1** shows, the proportion of total migration going to Florida and California has declined each decade since 1980, with California losing its second-place ranking in 2000 to a much less populous state, Arizona. Although the losses for Florida and California were relatively small, the trend is clear and persistent. These declines are particularly noticeable because the numbers of

Table 1 Ten states receiving the most in migrants age 60+ in 5-year periods ending in 1960, 1970, 1980, 1990, and 2000

	1960			1970			1980			1990			2000		
Rank	*State*	*Number*	*Percent*	*State*	*Number*	*Percent*	*State*	*Number*	*Percent*	*State*	*Number*	*Percent*	*State*	*Number*	*Percent*
1	FL	208 072	22.3	FL	263 200	24.4	FL	437 040	26.3	FL	451 709	23.8	FL	401 052	19.1
2	CA	126 883	13.6	CA	107 000	9.9	CA	144 880	8.7	CA	131 514	6.9	AZ	134 183	6.4
3	NJ	36 019	3.9	AZ	47 600	4.4	AZ	94 600	5.7	AZ	98 756	5.2	CA	127 693	6.1
4	NY	33 794	3.6	NJ	46 000	4.3	TX	78 480	4.7	TX	78 117	4.1	TX	101 446	4.8
5	IL	30 355	3.3	TX	39 800	3.7	NJ	49 400	3.0	NC	64 530	3.4	NC	77 720	3.7
6	AZ	29 571	3.2	NY	32 800	3.0	PA	39 520	2.4	PA	57 538	3.0	GA	63 120	3.0
7	OH	27 759	3.0	OH	32 300	3.0	NC	39 400	2.4	NJ	49 176	2.6	NV	62 155	3.0
8	TX	26 770	2.9	IL	28 800	2.7	WA	35 760	2.2	WA	47 484	2.5	PA	60 082	2.9
9	PA	25 738	2.8	PA	28 600	2.7	IL	35 720	2.1	VA	46 554	2.4	NJ	54 425	2.6
10	MI	20 308	2.2	MO	25 300	2.3	NY	34 920	2.1	GA	44 475	2.3	VA	53 776	2.6
Total Interstate Migrants		**931 012**			**1 079 200**[1]			**1 622 120**[2]			**1 901 105**			**2 096 841**	
Percent of Total in Top 10 States			**60.7**			**60.4**			**59.5**			**56.3**			**54.3**

Source: US Census.

[1]This figure was derived by extrapolating from a 1-in-100 sample. The actual census count was 1 094 014.

[2]This figure was derived by extrapolating from a 1-in-40 sample. The actual census count was 1 654 000.

interstate migrants leveled off between 1990 and 2000, causing the number as well as the proportion of migrants into Florida and California to drop in the past two censuses. It would be wrong, however, to predict the demise of Florida as the leading destination for retired migrants on the basis of these trends. It still attracts more later-life migrants than Arizona, California, and Texas combined.

Counties of Origin Out-migration in 2000, at least when it comes to large substate migration streams, was a metropolitan phenomenon with few exceptions. The majority (58) of the largest 100 streams across state lines between large counties or clusters of smaller counties (which the US Census Bureau calls PUMAs, for public use microdata areas) originated in metropolitan areas outside the Sunbelt, led by New York City, Los Angeles, and Chicago and their surrounding suburban counties. In 2000, the five boroughs that make up New York City sent 16 of the nation's largest streams to Florida and New Jersey, primarily the former.

The Los Angeles pattern is very different from that of New York City. In 2000, Los Angeles County sent seven large streams of retirees to locations in its three adjacent states: Arizona, Nevada, and Oregon. Adjacency, therefore, is at the heart of the Los Angeles out-migration pattern.

From the vantage point of Chicago, the popular Sunbelt destination states all seem about the same distance away. New York loves Florida, but Chicago plays the field. Retired Cook County residents are nearly ubiquitous. They are as apt to show up in southern California, Arizona, or Nevada as Florida. Of its nine major streams, seven go to these states.

Why should it be surprising that most retirement out-migration to interstate destinations is from metropolitan counties? These are the places of economic opportunity. More city retirees can afford to move and more have been geographically mobile during their working years.

The surprise in 2000 was that 42 of the largest 100 migration streams originated in the states that attract the most interstate migrants, all Sunbelt states. Thirteen are in Florida. There were far more interstate migrants who arrived in these Florida counties than who left them for counties outside of Florida. However, migrants of retirement age do leave Florida and other Sunbelt states. Indeed, Florida ranks third, below only New York and California, on the list of major sending states.

Receiving Counties Using the 2000 census microdata files, counties or county groups were ranked in terms of net interstate migration. Thirty-one of the top 100 destinations for interstate migrants, or nearly a third, were in Florida, in keeping with its longstanding status as the leading migration destination for older migrants.

Nationally, the leading substate destinations are located in coastal, mountain, and desert counties across the United States – from seaside Maine and Cape Cod in Massachusetts to the Puget Sound in Washington and coastal Oregon. Maricopa County, Arizona (Phoenix) and Clark County, Nevada (Las Vegas) rank first and third, respectively, and are the leading substate destinations in the west. Riverside County, California (Palm Springs) ranks 28th and is California's only entry on the list of major substate destinations.

Although the Sunbelt is generally the dominant regional destination, there is greater variety in destinations than is commonly assumed. Ocean County, New Jersey, for example, has consistently received enough retirees from New York and Pennsylvania to keep it among the top 100 interstate destinations for several decades.

Regional destinations disproportionately attract migrants from adjacent states. Examples are Cape Cod, Massachusetts, the New Jersey shore, and the Pocono Mountains of northeastern Pennsylvania, all located outside the Sunbelt. Other locations in the Appalachian Mountains and the Ozark region of Missouri and Arkansas are in the non-coastal Sunbelt. Southern and western Nevada and areas in the Pacific Northwest are all retirement areas of strong regional attraction and are frequently cited in retirement guides as good places to retire.

Migration Selectivity

Local movers over age 60 are generally not as economically and socially well off as non-movers, and migrants are the most positively selected. These differences have been relatively stable over time. Men and women are about equal in terms of making long-distance moves. Married couples predominate in this type of move. Perhaps unsurprisingly, the very old tend to move shorter distances. Migrants with the most education tend to move the farthest.

Studies comparing in-migrants with non-migrant age peers at their destination find that the migrants are financially better off. This is attributed to the tendency of migrants to move to locations with a somewhat lower cost of living than their origin. Cost of living and income is higher in larger cities. Also, moving is costly, so it tends to screen out those who cannot afford to move. Further, amenity migrants tend to move soon after retirement, before there is

any decay in their retirement income relative to more recent retirees.

Seasonal Migration

The US Census Bureau does not directly attempt to measure seasonal migration. There have been several surveys of seasonal migrants, however, conducted in Texas, Arizona, and Florida, that have provided snapshots of older visitors at their destinations. Data from these surveys are accumulating and are beginning to be compared, thereby providing a broader national picture. In this picture, the migrants are overwhelmingly White and retired. They are healthy, married couples in their mid- to late 60s with higher levels of income and education than the older population in general. One study compared samples of Canadians who wintered in Florida with US citizens who wintered in the Rio Grande Valley of Texas. The similarities between the two were impressive.

Climate is apparently a very strong factor in motivating seasonal migration. The propensity to seasonally migrate to Phoenix, Arizona, was highest in the northern plains and mountain states that border Canadian provinces. The trails that bring snowbirds south to Arizona or Florida are not strange or innovative; they follow the Sunbelt regional pattern noted previously. Perhaps the primary difference between seasonal and permanent migrants is that seasonal migrants sometimes travel farther, implying that the climactic change may be more important to them than it is to permanent migrants. The northward seasonal patterns from Florida and the desert states to cooler mountainous locations in North Carolina and New England in the east and to Colorado in the west have not yet been systematically studied.

The dialogue among researchers concerning whether seasonal migration is part of a process leading to permanent migration has concluded that seasonal migration generates its own lifestyle and culture, different from that of permanent migrants, but equally valuable. Once the lifestyle has been adopted, seasonal migration is likely to last for several years, finally interrupted or terminated by a fluctuation or decrease in necessary resources. Some do settle down and stay, but those are often people who have strong person ties in and place ties to the host community. They have family members and others living permanently nearby who tend to anchor them.

Counterstream Migration

Paired exchanges of migrants between some states are referred to as streams and counterstreams. The stream is the larger of the two. These paired exchanges are an expected part of the migration landscape. Furthermore, the migrants in the counterstreams are somewhat older on average, and more often are widowed and living dependently with relatives, than those who move in the larger streams.

Using 1990 census data to compare the 50 largest pairs of streams and counterstreams, researchers found three geographical patterns. The first involved exchanges between Florida and some of its major partners. The streams flowed into Florida, of course, with counterstreams moving in the opposite direction. The second geographical pattern was exchanges between California and adjacent or regional states. The smaller counterstreams flowed back to California. The third pattern, also regional, was the Mid-Atlantic exchange system, which involved streams out of New York to three adjacent states, Pennsylvania, New Jersey, and Connecticut, with counterstreams back to New York. These three exchange patterns continued to hold in the 2000 census.

These findings led to the speculation that counterstreams contain large proportions of returning migrants who had moved at an earlier time to a popular destination and are later returning to the state from which they had come. This speculation is bolstered by data showing the large proportions of migrants in counterstreams who are returning to their states of birth.

Return Migration

It was once thought that a majority of migrating retirees were likely to be returning to their home state. This popular myth was squashed by a study that showed that the return migration rate of older migrants, in 1970, was identical to that of all migrants, about 20%. More recent research shows that return migration is waning slowly among retirees. The rate of return migration was 18.6% in 1980, declined to 17.5% in 1990, and leveled off at 17.5% in 2000.

All of the reports on older return migrants have found that some states and regions are more popular with return migrants than others. For the year 2000, after subtracting out all persons leaving their state of birth (because they cannot be return migrants), 29% of the remaining older migrants were returning to their home states. North Carolina and Florida attracted half of their potential return migrants, whereas Wyoming and North Dakota attracted less than 15%. The pattern is unstable from one decade to another.

A popular ethnic explanation for return migration to the south and southwest concerns the return migration of African Americans and Hispanics. Regional return migration involves a historical work cycle. Industrial states recruit workers from rural

parts of the country. Streams of workers continue to tie these sending and receiving states together. However, over time, return migration streams develop that carry some of the retired workers back to their states of birth. These return streams build in a delayed but roughly proportional response to the earlier stream development for work. Although the principle applies to all, it is easier to discern when combined with ethnic identification.

In this context, it is not surprising to find that a majority of African American migrants age 60 and older are moving into the southern states. Nor is it surprising to find that return migration rates are high among these migrants. It is too early in the process of industrial recruitment of Hispanics to see high rates of return migration among Hispanics from Illinois and Michigan to the southwest. However, projecting from the African American work and retirement migration patterns, it would not be surprising to find such a development in the future.

There are two additional types of return migration discussed in the literature. The first is 'provincial return migration,' a subset of amenity migration. It consists of lifestyle-motivated movers who choose to move to their states of birth. They are younger, slightly better educated, more affluent, and far more often married than return migrants in general. The second type, 'counterstream return migration,' is a subset of 'dependency migration,' a move undertaken to gain assistance in activities of daily living. Interregional migration, returning to states of birth in the northeast and midwest, fits the aggregate description of counterstream return migration, and interregional migrants to the south and southwest fit the aggregate description of provincial return migration.

Metropolitan and Non-metropolitan Migration

One of the macro-level processes that affect geographical mobility in our time is metropolitan deconcentration. The long-term trend of population movement to cities slowed and reversed in the 1970s. Older people were in the vanguard of migration to non-metropolitan counties; the turnaround for them happened in the 1960s.

About three-fourths of later-life migrants move from metropolitan areas. Nearly that proportion of metropolitan out-migrants move to other metropolitan areas, but they tend to move to a smaller city, thereby increasing their quality of life by lowering the hassle factor. Although amenity migrants express a desire for a change of surroundings, they do not want to give up completely the comforts afforded by an urban lifestyle. Locations that are reasonably proximate to cities are especially attractive if the cultural and service amenities these migrants expect (e.g., museums, restaurants, theater, shopping, and an international airport) can be found in a city just an hour or two away. Sun City was built near Phoenix for a reason. And it is unthinkable that Cape Cod would have developed as it has without its proximity to Boston. One migrant described living on Cape Cod as 'the best of both worlds,' a place somewhere between the remoteness of rural living and the fast-paced life of the region's metropolitan centers.

Migration Impact

Economic Impact The 1990s began with a spate of articles considering the economic impact of retirees at their destinations. A sizable amount of annual income is transferred to and from states as a result of interstate migration. This money tends to concentrate, of course, in the major destination states. Unfortunately, a comprehensive measure of consumer spending is not included in the census. Income in these studies is a proxy for consumer spending.

During the same period, 515 rural counties, in which the older population was growing through migration, outperformed non-metropolitan area averages for job growth, ostensibly a result of retiree consumer spending. Other studies seemed to support these findings. By the end of that decade there was nearly complete consensus among researchers that the economic impact of retirement migration is positive.

Local Political Activism and Support for Public Services The positive economic impact must be balanced against a negative effect for public school financing. Local voting studies have examined the results of local school budget referenda. A study using the results of school district bond elections in Florida found that a higher percentage of elderly residents and voters in a school district predicted a lower level of support for schools. Citizens, and older citizens in particular, were much less supportive of public services, such as schools, that they did not expect to use. This does not imply that only older citizens, or the migrants among them, vote against school bonds. Younger persons without children and those who send their children to private and parochial schools tend to do the same.

Impact on Community Social Structure and Values Retirement enclaves in rural counties often tend to be worlds unto themselves, relatively unattached to local social structure. They are essentially 'common interest developments.' This social isolationist view is no longer normative. Migrants are sometimes seen as proactive agents of change in their

communities. For example, middle-class amenity migrants are likely to band together to protect the environmental ambiance of the community. Chambers of commerce trying to recruit both retirees and industry to their communities could find the retirees actively opposing industrial development on environmental grounds.

See also: Life Course; Retirement.

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Mitochondria and Aging

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Glossary

Apoptosis – Cell death.

Introduction

The mitochondrion has long been viewed as the Achilles heel of a cell. It is essential for energy production, yet the oxygen radicals generated during oxidative phosphorylation (OXPHOS) as well as the susceptibility of the mitochondrial genome to damage suggest a role for mitochondria in the etiology of aging processes as well as in age-related diseases. Oxidative phosphorylation occurs within the mitochondria, generating both ATP and, as a by-product, reactive oxygen species (ROS). The requirement for functional mitochondria (i.e., production of ATP) as well as the production of ROS make mitochondria pivotal players in the aging process and has led to the mitochondrial theory of aging. This theory, first developed by Denham Harman in 1956 and further refined by Jaime Miquel in 1980, states that aging results from an accumulation of oxidative damage to mitochondrial DNA (mtDNA), resulting in an accrual of damage to proteins critical to OXPHOS and energy production.

Evidence for the role of mitochondria in the aging process is provided by cell culture studies in which the mitochondria from old cells are isolated and then microinjected into mitochondria-less young cells. The young cells undergo a cellular degeneration not observed in young cells repopulated with young mitochondria. Age-related dysfunction of mitochondria has the potential to trigger cellular damage through a number of routes and can be manifested by a number of effects: oxidative damage to macromolecules (proteins, lipids, and nucleic acid), accumulation of mutations in the mitochondrial genome, and changes in the ability of the mitochondria to respond to apoptotic signals. Although there is a plethora of data to support each of these events, neither the cause and effect nor the synergistic effects of these events have been completely elucidated. Since damage to the mitochondria is hypothesized to result in cell death, ascribing the fate of these cells is complicated. This problem was described by the late George Glenner as the Mafia syndrome, i.e., the fatally affected cells cannot be found because the bodies have been assassinated and removed.

Approximately 90% of cellular oxygen is metabolized in mitochondria, with 1–5% of this being

converted to ROS as a normal by-product of electron transport system (ETS) activity. Mitochondria may, therefore, be the primary cellular source and target of endogenous ROS. Oxidative damage, secondary to endogenous or exogenous free radicals, is hypothesized to accumulate throughout the lifetime of an organism, eventually giving rise to physiological and structural changes that are recognized as aging. This is reflected in skeletal muscle by the age-associated increases in oxidative damage to proteins, lipids, and nucleic acids. ROS can directly modify proteins, forming protein carbonyls. In addition, carbohydrate and lipid derivatives can react with proteins to form adducts that can be analyzed. Protein carbonyl content (PCC) is the most widely used marker of oxidative modification of proteins. There are several methodologies for the quantitation of PCC; in all of them 2,4-dinitrophenyl hydrazine is allowed to react with the protein carbonyls to form the corresponding hydrazone, which can be analyzed optically by radioactive counting or immunohistochemically. Using PCC as a marker, it has been shown that oxidative damage to proteins correlates well with aging processes.

Lipid peroxidation is another type of oxidative damage that has been extensively studied with respect to age. The allylic hydrogens in the polyunsaturated fatty acid components of phospholipids in cellular membranes make the membranes sensitive to oxidation by free radicals. Lipid peroxidation is relevant to the aging process because increases in peroxidation result in decreased membrane fluidity and increase the leakiness of membrane bilayers. The measurement of lipid peroxidation has, however, been complicated by the lack of specificity of a number of the biomarkers originally measured. More recent means of determining lipid peroxidation have demonstrated that peroxidation increases dramatically with age.

The mitochondrial genome may be particularly susceptible to oxidative damage during aging. Mitochondria contain their own circular, double-stranded genomes (2–10 per mitochondria) that replicate independently of the nuclear genome. The mitochondrial genome is located in close proximity to the source of ROS and lacks cognates of the nuclear histone proteins that confer protection from ROS. Of the three principal DNA repair activities detected in the nucleus (i.e., base excision, nucleotide excision, and recombinational repair), nucleotide excision repair activity has not been detected in mammalian mitochondria. Oxidative damage to mtDNA increases with age in human brain, diaphragm, heart, and lung and in mouse liver and may directly disrupt mitochondrial gene expression or cause mtDNA mutations. For example, a specific oxidative DNA lesion, 8-hydroxydeoxyguanosine (8-OHdG), causes point mutations *in vitro*.

The generation of transgenic mice expressing a proofreading-deficient mitochondrial polymerase γ provided an animal model for determining the effect of mtDNA mutations on aging processes. These mice displayed a premature onset of many aging-related phenotypes, including weight loss, reduced fat, osteoporosis, and cardiomyopathy. Molecular characterization of the mtDNA in these animals demonstrated an increase in the number of point mutations and deletion mutations in the mtDNA, providing a causative link between mtDNA point mutations and tissue damage.

Damage to mtDNA directly impacts the ability of the mitochondria to function normally. The mitochondrial genome, in mammals, is approximately 16 kb in length and encodes 22 tRNA, 13 subunits of the ETS, and its own 16S and 26S ribosomal RNAs. It is a very compact genome lacking noncoding regions with the exception of the D loop (control region), responsible for controlling initiation of replication and transcription. The mitochondrial transcripts are synthesized as long polycistronic messages and are transcribed from both strands. The mitochondrial genome encodes 13 subunits of four protein complexes critically important for the functioning of the ETS and OXPHOS pathways. All other proteins required for maintenance of mitochondrial function are encoded in the nucleus, synthesized in the cytosol, and imported into the mitochondria by specific targeting sequences at the N-terminus of the proteins. Oxidative damage to, or mutation of, the mitochondrial genome may affect the activity of those ETS complexes to which this genome makes its largest polypeptide contributions, namely, complexes I and IV (i.e., NADH dehydrogenase and cytochrome *c* oxidase [COX], respectively). Biochemical analyses of tissue homogenates identified decreased complex I and IV activities with age in postmitotic tissues that rely heavily on the ETS and OXPHOS such as brain, heart, and skeletal muscle. *In situ* histochemical studies demonstrate increased abundance of ETS abnormal cells with age in a variety of tissues including heart, extraocular muscles, limb muscles, parathyroid, and diaphragm. An absence of cytochrome *c* oxidase activity (COX^-; three subunits encoded by the mtDNA) is the most commonly reported abnormal ETS phenotype and is often observed with a concomitant increase in the entirely nuclear-encoded ETS complex, succinate dehydrogenase activity (SDH^{++}). The SDH hyper-reactivity is likely due to compensatory nuclear upregulation of mitochondrial biogenesis. The SDH^{++} phenotype (typically in combination with the loss of COX activity) within a

skeletal muscle fiber represents the ragged red fiber (RRF) phenotype observed in Gomori trichrome staining of skeletal muscle from aged individuals or those with mitochondrial myopathies.

mtDNA mutations have been shown, in humans, to result in a number of diseases, including myopathies and encephalopathies, a broad class of conditions characterized by muscle weakness and central nervous system dysfunction. Myopathies can be divided into two major groups: those caused by a single mtDNA base substitution, such as Leber's hereditary optic nerve atrophy and myoclonic epilepsy and ragged red fiber (MERRF), and diseases caused by large mtDNA deletion mutations, including chronic progressive external ophthalmoplegia (CPEO) and Kearns-Sayre syndrome (KSS). In myopathy patients, the levels of the mutated mtDNA genomes are very high, 73–98% mutated mtDNA in symptomatic MERRF patients. Deletion mutations are generally present as 20–80% of all mtDNA genomes in KSS patients. Cybrid cell studies of myopathic mitochondrial deletions demonstrate decreases in cell growth, ETS/OXPHOS activity, mitochondrial membrane potential, and rate of ATP synthesis, suggesting that similar *in vivo* deficits may occur in ETS abnormal cells or segmental portions of muscle fibers.

Age-related mitochondrial dysfunction also plays a critical role in both the initiation and progression of a number of age-related diseases. Somatic mutations in the mitochondrial genome have been linked to Parkinsonism, late-onset sporadic Alzheimer's disease (AD), and Wilson disease, to name a few. A substantial body of evidence suggests that mitochondrial dysfunction, the resultant increase in ROS production, and decrease in energy production are responsible for the loss of neurons in AD.

Direct evidence for the age-dependent accumulation of mtDNA abnormalities required the development of the polymerase chain reaction (PCR), a technology that provided the sensitivity necessary to identify these abnormalities in tissue homogenates. Initial studies focused on human tissues and identified an age-associated increase in a specific 4977 bp mtDNA deletion mutation, often termed the common deletion. Subsequent studies identified other mtDNA deletion mutations to accumulate with age in a variety of species, including humans, rhesus monkeys, mice, and rats. These studies, largely based upon the analysis of tissue homogenates, demonstrated that mtDNA deletion mutations increase in frequency with age. Accurate estimates of the abundance of these abnormalities required the design of experiments that considered the focal (and not homogeneous) distribution of these abnormalities.

Initial quantitation experiments of aged human tissue utilizing radioactive PCR methods determined the abundance of the specific deletion mutation, $mtDNA^{4977}$, to be $<0.1\%$ of the total mtDNA present in the tissue homogenate. The low abundance of this deletion led to the speculation that mtDNA deletion mutations are of minor physiological significance and impact. All of the initial quantitative analyses, however, were performed using cellular homogenates, in which thousands of cells were present. Estimating the abundance of mtDNA deletion mutations from homogenates assumed an equal cellular distribution of the deletion-containing genomes, an assumption subsequently determined to be incorrect. *In situ* hybridization analyses of aged muscle tissue provided the first evidence of a focal accumulation of mtDNA deletion mutations. The initial *in situ* hybridization studies of age-associated mtDNA deletion mutations were performed on human skeletal muscle and were focused on the detection of common mtDNA deletion mutations. Using mtDNA probes located either within or outside the deleted regions, high levels of mtDNA deletion mutations were localized to individual cells, suggesting that deletion mutations accumulate focally and that neither their abundance nor distribution can be accurately assessed in cellular homogenates.

Histological examination of tissues, particularly skeletal muscle, using stains for the activity of mitochondrial ETS enzymes has facilitated an analysis of the physiological effects of mtDNA deletions. Dramatic changes in the activities of two ETS enzymes, COX and SDH, were observed in myopathy patients and were later demonstrated to occur in a number of different mammalian species with age. These two enzymes were monitored because several of the COX subunits are encoded by the mitochondrial genome and, thus, would be indicative of changes in the mtDNA. Although SDH is entirely encoded by the nuclear genome, decreases in mitochondrial energy output results in a compensatory upregulation of nuclear encoded genes.

One example of the impact of mtDNA deletion mutations occurs with sarcopenia, the age-related loss of muscle function, fiber mass, and fiber number. In the skeletal muscle of rodents, humans, and rhesus monkeys, intrafiber increases in mtDNA deletion mutation abundance are closely linked with declines in ETS enzyme activities and with physical changes in muscle fibers. For these studies, muscle tissue was examined histologically by staining consecutive slide sections for COX and SDH activity. Using these two enzymatic stains, the age-dependent increase of ETS abnormalities has been demonstrated in several different muscles and animal models. When these

abnormal fibers are followed histologically along their length (longitudinal analysis), many of the ETS abnormal fibers displayed an overt decline in cross-sectional area (intrafiber atrophy) within the ETS abnormal region of the fiber. The cross-sectional area of the ragged red region is smaller than that observed in normal fibers, and the longer ETS abnormal regions are more likely to atrophy than shorter ETS abnormal regions. Longitudinal analysis of atrophied fibers also showed some decrease in cross-sectional area until they are no longer observable by light microscopy, suggesting that they are broken. The fiber can often be found again several sections later. These data clearly demonstrate that ETS abnormalities have a localized physiological impact on the cell and can result in fiber atrophy and fiber breakage.

By focusing on cells displaying an ETS abnormal phenotype, it is possible to specifically define the mtDNA genotype (mutation) associated with that phenotype in a single cell. A single section of a cell can be captured by microdissection, the DNA isolated from the cell and the mtDNA amplified using PCR. In all cases, the mtDNA deletion mutations were concomitant with the COX^{-}/SDH^{++} regions of affected muscle fibers. When ETS normal regions of the same muscle fiber (i.e., from sections further along the fiber) are analyzed, only full-length wild-type mtDNA genomes are identified. When the same ETS abnormal region was sampled in two different places from the same fiber (i.e., 70 μm apart), the same deletion product was obtained, demonstrating that mtDNA deletion mutations are clonal events. These studies suggest a process in skeletal muscle initiated by the mtDNA deletion mutation that accumulates, triggering the COX^{-}/SDH^{++} phenotype and, ultimately, fiber atrophy and fiber breakage.

Point mutations in the mtDNA have also been demonstrated to accumulate with age. Initial efforts emphasized single nucleotide changes associated with mitochondrial myopathies, and the point mutations characteristic of MERRF and MELAS (mitochondrial myopathy, encephalopathy, lactic acidosis, and strokelike episodes) were identified in normally aging humans. Many other myopathy-related point mutations have been examined in aging humans using tissue homogenates. Although these studies produced variable results, point mutations in homogenates from various tissues of aging individuals are present at very low levels (0.04–2.2%) compared to levels in myopathy patients.

Point mutations can be detected when they have clonally expanded within a mitochondrial population, i.e., when they occur in the germline and are present throughout all tissues. If, however, point mutations accrue at low levels randomly throughout the mtDNA genome, detection becomes much more difficult. The aggregate burden of mtDNA point mutations can, however, be determined by cloning and sequencing a specific region of the mtDNA genome. For example, a PCR-cloning-sequencing strategy has demonstrated that mtDNA from brains of elderly humans has a higher aggregate burden of mutations than mtDNA from younger patients. These mutations were, in general, individually rare point mutations. Interestingly, although the aggregate burden of point mutations is high, the majority of the mutations are rare. When single cells were analyzed, point mutations were observed to accumulate to high levels in an age-dependent and tissue-specific manner. Several specific point mutations occur at high levels (up to 50%) in skin fibroblasts from individuals older than 65 years, but the same mutations are not observed in muscle from the same individuals. The absence of a readily detectable phenotype (like the COX^{-}/SDH^{++} observed with deletion mutations) makes the physiological relevance of these mutations difficult to determine.

The lack of overt phenotypes has hampered attempts to relate point mutations in mtDNA to the aging phenomenon, although the mutations appear to increase with age. Cellular impacts of age-associated point mutations in mtDNA have not been reported. The point mutations in the control region of mtDNA may have little impact on cellular physiology, so cells could accommodate and accumulate them to high levels. If single cells can accumulate high levels of point mutations and still function within normal parameters without expressing abnormal phenotypes, point mutations may be an age-associated phenomenon, but not causally linked to aging.

It has been difficult to determine the cause of mtDNA mutations (both deletion and point). It was initially suggested that oxidative damage was the causal factor in initiation of deletion and point mutations events. Although the amount of oxidative damaged mtDNA has been shown to increase in tissue homogenates with age, the demonstration of causation has been much more difficult. Oxidative damage can be detected in atrophic, ETS abnormal cells but not in the adjacent ETS abnormal regions that are not atrophic, suggesting that the oxidative damage detected was a result and not a cause of mtDNA mutations.

Dietary restriction (DR), the restriction of calories without malnutrition, is the most successful anti-aging intervention tested to date in mammals, greatly extending maximum life span and keeping animals younger longer. Reduction in oxidative stress is a feature of DR in skeletal muscle in mice. DR

attenuates the age-associated increase in rates of mitochondrial ROS and H_2O_2 generation and reduces the accrual of oxidative damage. Mitochondrial function is also preserved with age in skeletal muscle from DR animals as indicated by decreased alkane production, delayed loss of membrane fluidity, and increased metabolic potential compared to control animals. In the studies of sarcopenia described previously, adult-onset DR has a protective effect on skeletal muscles, reducing muscle mass loss and maintaining fiber number.

Mitochondria also play a critical role in cell death pathways, particularly apoptosis. Proteins localized within the mitochondria are involved in the activation of the caspase proteases, initiating a series of events that result in cell death. In apoptosis, a transient opening of the mitochondrial permeability transition pore of the mitochondrial inner membrane results in the movement of cytochrome *c* from the intermembrane space of the mitochondria into the cytosol. In the presence of dATP, cytochrome *c* forms an apoptosome with Apaf-1. This apoptosome activates a protease cascade resulting in apoptosis. Changes in mitochondrial function with age appear to have confounding effects on apoptosis, dependent on the cell type involved. Mitochondrial dysfunction in certain cell types, such as neurons and cardiomyocytes, results in the initiation of apoptosis and subsequent loss of these cell types. These apoptotic events may be critical in diseases such as age-related dementia and cardiac dysfunction.

Mitochondrial dysfunction can also, however, affect the cell death pathways. In cell culture, the lack of mtDNA in hepatoma cells makes these cells resistant to apoptosis. It has also been demonstrated that a lack of ATP production is sufficient to switch the cell death pathway from apoptotic to necrotic. The inability of the tissue to rein in aberrantly dividing cells is a key step in the development of cancer cells.

In summary, the mitochondrion, although essential to the functioning of eukaryotic cells, can lead to the degeneration of a cell. Chronic exposure to ROS, a by-product of oxidative phosphorylation, damages many macromolecules, including DNA, lipids, and proteins. Age-dependent increases in the somatic mutations of mtDNA, particularly deletion mutations, affect both OXPHOS and ETS activities in a cell. The resultant declines in energy production and increases in ROS production lead to cellular dysfunction and, ultimately, tissue/organ dysfunction.

Acknowledgments

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See also: Cell Death; Dementia: Alzheimer's; DNA and Gene Expression; Oxidative Damage; Theories of Aging: Biological.

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Mobility and Flexibility

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Glossary

Mobility – The physical ability to move and the possibility to realize trips and activities outside the home.

Introduction

This article deals with an essential precondition of older adults' independent living and societal participation: the ability and possibility to move about. In principle, mobility constitutes a basic need and behavior of people of all ages. This statement applies to both the fundamental physical capacity to move and the farther-reaching ability to travel for bridging spatial distances between spheres of life that are

central for enabling every individual to conduct an autonomous lifestyle and maintain connectedness with his or her community and culture. These conditions of mobility are usually taken for granted. With advancing age, however, mobility is increasingly jeopardized. Aging is accompanied by the growing risk of physical disabilities and declining sensory abilities, and hence restriction of mobility. Outside the home, unfavorable circumstances such as inaccessible buildings and modes of transportation, the replacement of previously personal services by machines, and the speed and complexity of traffic can further complicate older adults' ability to move about. At the same time, the importance of mobility increases, because social changes such as grown children leaving home, retirement, and the loss of close confidants demand a growing measure of mobility and flexibility if the elderly individual is to continue being part of society.

Moreover, mobility and flexibility are crucial to modern industrialized societies. This holds for mobility in the sense of social mobility, including the dissolution from social classes and hereditary positions, and the loosening of binding social roles and norms that have led to the pluralization of lifestyles and variety of life course regimes. It goes also for mobility in the sense of geographic mobility, including the migration of individuals or groups, moving from one place to another and traveling to attractive destinations in an increasingly global world (although that may not apply to the whole of the population), and not least in the sense of the actual journeys performed by each member of society, whether by foot or employing any means of transportation.

In connection with this historical development emerged the association of mobility with modern values such as autonomy and freedom of choice, flexibility, and variability of behaving and thinking. As a result, mobility implies highly appreciated societal goals and symbolic meanings in addition to its significance as human need for physical movement and functional necessity to overcome distances between different locations.

As various as the components of mobility are, as manifold are the theoretical and empirical approaches addressing them. As for the micro-level of person-related physical, sensory, and cognitive competencies and impairments, of individual motivations and behavior, and of sociodemographic and structural aspects, behavioral and social as well as medical sciences are in demand. Sociological theories are also needed concerning the macro-level of societal and technological conditions and related developments. Traffic and transport policy and research are just as relevant as geography and urban planning, architecture, and vehicle engineering. Further disciplines may be necessary depending on the focus of interest.

In an article like this it is not possible to do justice to all of these aspects in detail. Therefore, it concentrates on those aspects that can be considered most relevant for older adults' out-of-home mobility from a social science perspective. It proceeds as follows: first it traces back why mobility and flexibility have become so significant in modern society and shows the many facets accumulating in this phenomenon. Second, the main components of older adults' mobility and the respective theoretical views and empirical findings concerning these components are presented. Whether the increasing number of old and very old people can move about and get to places to which they wish or need to get depends on various personal resources and environmental circumstances. These conditions are dealt with in the next section. The article continues by pointing to a range of future challenges to mobility and possible improvements for meeting older adults' mobility needs and flexibility desires. And finally, it tries to link the different strands in a more holistic concept of older adults' mobility.

The Significance of Mobility and Flexibility in Modern Societies

Historic Developments

In order to understand the tremendous importance mobility has gained in current society it may be useful to locate it in a larger historical context.

In the sense of the physical ability to move and to flexibly take up the demands of the social and physical environment, mobility has constituted a key to survival of the human species. For centuries, mobility has meant locomotion on foot or on horseback and travel by cart or boat. Over the course of the nineteenth century, industrial development opened up new opportunities for individual mobility and traffic. After its first run between Liverpool and Manchester in 1830, the railroad quickly gained ground. As steam and rail technology improved and electric power became practical, railways became the dominant means of land transport in many parts of the world for nearly a century.

After a delay of a few decades, progress in aviation occurred. The turn of the century saw the first motor planes, and 1911 the first transcontinental flight. Commercial aviation took hold in the 1950s and 1960s, and from 1969 on the Boeing 747, the largest passenger-carrying aircraft ever built, started to revolutionize commercial air travel. Meanwhile, mass tourism is an important industry worldwide.

The automobile developed much faster. Just 14 years after the first practical gasoline-powered automobile, which drove on German roads in 1886, there existed about 12 000 automobiles worldwide. From 1908 on, the assembly-line mass production of cars has developed, and meanwhile, the automobile has become the preferred means of transportation. Simultaneously, the length of the motorway network grew while the length of the rail networks contracted.

Altogether, these technological developments, accompanied by corresponding organizational transformations, led to mobility and travel increasing continually. Whereas estimated global traffic volume amounted to approximately 5.5 trillion person-kilometers (motorized mobility per capita in 11 world regions) in 1960, this figure had risen to 23.3 trillion in 1990. The distances traveled have increased in particular, because while transport technologies have improved, the shape of urban and rural settlements and the constitution and nature of neighborhoods have changed as well. Underground and street railways built in large cities and the provision of extended road infrastructure accelerated extensive suburban development and the establishment of industrial and commercial enterprises beyond residential areas. The growing dispersal of travel origins and destinations, in turn, increased the importance of mobility for bridging the widening gap between functional areas.

Looking for causal directions in this close relationship between transportation and land use will probably be in vain. The question of whether transportation infrastructure influences urban form or whether land use patterns impact travel behavior has been discussed in theory and empirical studies for many years. One can assume that both directions are partial equilibrium and interdependent interactions. In any case, the interrelated trends of advances in transport options and urban sprawl complementing one another have contributed to the fact that for every member of society, mobility has become a major condition of ensuring the ability to lead an autonomous life and participate actively in society.

The Subjective Meaning of Mobility

There is increasing empirical evidence that older adults' diminishing actual mobility as it was observed in many studies (usually measured as frequency of trips made – see next section) does not correspond to their needs and wishes. As early as the 1980s, Carp (1980: 140) stressed the importance of mobility in old age: "In modern society old people, like those of other ages, must go outside their homes to provide for maintenance needs as well as for sociability and recreation." If life is to have an acceptable quality, she argued, needs such as those expressed in, for example, trips for relaxation and enjoyment are as essential as shopping trips or commutes to work, and they are requisite to independent living.

A series of European studies demonstrated that the possibility to move about and to pursue outdoor leisure activities contributes significantly to older adults' subjective quality of life. Lower trip rates did not correspond with lower levels of desire to do certain trips, especially leisure-related trips. Instead, older people who were limited in their mobility either by health impairments or by the lack of a car were less satisfied not only with their possibilities for reaching the destinations they wished but also with their possibilities for participating in leisure activities. In addition, individuals themselves place a high value on the ability to move about. Statements like "It's everything, it's life," clearly show that mobility means much more than merely a derived demand. In the United States, similar answers were received with respect to the meaning of transportation, albeit mostly related to being able to drive a car. Elderly people described the strong linkage between transportation, independence, and overall life satisfaction. Thus, individual needs and societal necessities, economic interests, and modern values mutually reinforcing each other have resulted in mobility as an increasingly important precondition of maintaining quality of life and well-being in aging individuals.

Theoretical Views and Empirical Findings

The out-of-home mobility of aging and aged persons is a complex phenomenon that cannot easily be captured. It is complex, because so many different aspects come together with this interaction between persons and their environments. As shown previously, mobility means both the physical ability to move and the realization of all types of trips and activities outside the home. It can be motivated by diverse, often inseparably intertwined motives and manifested in a goal-directed mode or for its own sake. Actual travel can be performed by foot or by employing any mechanized or motorized means of transportation. Furthermore, spatial and traffic conditions and context for mobility can differ widely. The persons themselves who move, walk, drive, travel, etc. are different with respect to their individual health and mental states, economic and social resources, and their mobility may depend on individual capacities, attitudes, and interests. These different aspects have been addressed from diverse perspectives. In the following sections, the most important approaches are discussed.

The Health Perspective

Whether elderly men and women can fulfill their mobility-related needs and desires and how they manage as they go about their daily affairs and out-of-home activities depend first of all on their state of health. All kinds of movements demand a minimal amount of physical and cognitive capacity, for walking, cycling, driving, or using any other means of transportation. In this respect, the process of aging is accompanied by multiple changes. For decades, a broad range of research has been conducted to understand, among other areas, the increasing decline in mobility performance, including decrements in motor control and force production and regulation; loss of voluntary strength; reduced sensory abilities and sensorimotor integration; slowing motor action and speed of processing; shrinking range of motion and flexibility; and decreasing ability to stabilize posture, resulting in an increased risk for falls. All of these age-related changes may restrict older persons' ability to ambulate and move about.

As there exist excellent comprehensive reviews and contributions on specific aspects of these issues, they are not further addressed here. However, it is worth mentioning that although the deficiencies in walking, visual acuity, hearing, memory, etc. can be substantial, they do not automatically confine all older individuals to their homes. Moreover, there is evidence that physical activity and regular training can minimize the decline in motor function.

Furthermore, functional decline is significantly related to demographic characteristics, lifestyle, social relations, and neighborhood conditions. Difficulties in getting about outdoors were found most frequently among women of older age and among elders with low education, lower income levels, and previous chronic conditions; people with few social contacts; and those living in problematic neighborhood environments. Obviously, conditions of physical and cognitive impairments interact in a complex fashion with sociophysical environments.

The Environment Perspective

The outdoor environment with its various physical-spatial and social components constitutes both the target and context of older adults' mobility. Shops and service facilities, recreational spots and favorite restaurants, a close friend's home or a medical care facility: all of these and many more close or distant places can be a target, and every action undertaken to get such a target always takes place in a concrete spatial context. From the perspective of environmental gerontology as formulated by Lawton and colleagues in the early 1980s, mobility can be regarded as a prototypical person–environment interaction. On the one side, the aging individual with his or her competencies and impairments, needs and desires, is involved. On the other, the specific sociospatial characteristics of the environment are concerned. Both the social and physical environments are inseparably interwoven and can constitute at the same time major resources and constraints for an aging individual's potentials and scope of action, because they can differ widely. This holds for general features like a region's geographical, topographical, and climate characteristics, welfare systems, and the various kinds of urban or rural settlements, and for the immediate natural and built surroundings, including, for instance, social networks and other traffic participants, neighborhood and community conditions, and the modes of transportation one can use to achieve out-of-home goals. Environmental conditions can be safe or dangerous, provide a variety of shops, medical services, and leisure facilities, and offer a dense and accessible network of public transportation systems – or can hinder people because of lacking opportunities, unfavorable distances, or traffic density, noise, and inconsiderate road users.

Service and Security Aspects Since Carp's early studies on environmental effects upon the mobility of older people, several studies have shown that characteristics of the area in which older adults live strongly affect their mobility and related activities. Generally, facilities for daily necessities and cultural opportunities are less accessible and adequate health and community-based services are less abundantly available in rural than in urban areas. Moreover, rural areas are often characterized by a lack of public transit services. Thus, and not surprisingly, older adults in rural areas can reach basic facilities less often on foot or by public transportation than their urban counterparts. Instead, they have to use the car more often, both as driver and as passenger.

Rural elders, in general, go out less than older urbanites. They are also less satisfied with their possibilities to be mobile and active, and they would like to take more trips than they actually do. The factors impeding their access to important facilities are mainly related to health and great distances. Hence, the less competent an individual is, the greater the impact of environmental factors, and the greater the importance of neighborhoods that provide easily accessible amenities nearby for maintaining independent living.

Findings on urban–rural differences in health status are, however, inconsistent. US studies showed that rural and urban older persons did not differ significantly regarding chronic health problems, although there is some evidence that some dementing

illnesses are more prevalent in rural regions. Similarly, no, or only slight, differences between urban and rural areas were found regarding functional health in a recent European study.

Apart from the accessibility of services, facilities, or public transportation, the fear of crime can influence mobility-related decisions and inhibit outdoor behavior in a specific residential area. Security does not seem to be a concern for most older adults living in the countryside, whereas in urban areas there are substantial percentages of people who perceive their local environment as unsafe.

Social Aspects Regional conditions – especially those relating to distances between places of residence – also affect the frequency and nature (personal, technically mediated) of social contacts and activities that are crucial prerequisites for satisfactory aging. The transportation times needed in, for instance, large metropolitan areas or sparsely settled rural regions increase the difficulties of maintaining social relationships. At the same time, the social context affects older adults' out-of-home mobility: those with a diversified social network make more trips than older individuals without persons outside their household who are important to them for emotional or personal reasons.

In an analysis of visually impaired elders' out-of-home activities in Germany, the motivation to go out was significantly associated with social resources in urban but not in rural areas. This might be related to the greater geographical distances to important persons in cities. That is, in urban areas one might have to be more motivated to go out to maintain social relationships. Older urbanites live generally farther away from their most important confidants than older adults in rural areas, and the closer an individual lives to important persons, the more frequently they meet. However, it might also be that in urban regions social resources enhance outdoor motivation because social contacts with others living farther away might be an important reason to go out.

Spatial Aspects Clear differences in older adults' spatial mobility patterns reveal when differentiating by residential location. 1995 Nationwide Personal Transportation Survey (NPTS) data show that elders living in suburban or rural areas made more trips, traveled longer, and used the car more often than those living in high-density urban areas. However, living in high-density urban areas is usually related to age, family size, and income, all of which are also associated with less travel.

Regarding the impact of different kinds of neighborhoods on trip frequency, findings suggest that compared with conventional neighborhoods, single-family households in neo-traditional neighborhoods make a similar number of trips, but substitute walking trips for driving trips. Characteristics of the residential environment seem to affect the modal choice of older people who do not have a car of their own. If they own a car, they often use it, independent of where they live. Evidence from a review considering differing neighborhoods suggests that beyond sociodemographic predictors, environmental characteristics such as higher density, greater connectivity, and more land use mix contribute to higher rates of walking and cycling.

The spatial range of older Europeans' out-of-home mobility – and thus their activity space – is quite restricted. Forty-four percent of the trips have a destination within a circle of 1 km, and an additional 24% between 1 and 3 km. Only 14% of the trips go further than 10 km from home. But as in the United States, the range of mobility is larger in rural than in urban areas. While in most European urban areas the elderly can reach essential facilities mainly on foot or by public transit, they often depend on a car or on other (family, formal) transportation support in rural areas. It is no wonder that rural elders are usually better equipped with private cars than elders living in urban areas. Exceptions are, on the one hand, countries such as Italy, where car ownership among older adults is generally high (about 83%), and on the other, countries with a low level of individual motorization, such as Hungary (36.5% car ownership in the city and 17.4% in the rural area).

The Transport Perspective

In transport research and planning, mobility usually has been defined as locomotion, as a movement in time and space. It is measured in terms of trips or journeys made and reported in standardized diary forms. Information is generally collected and provided on travel origins and destinations, distances, travel modes used, periods of time, and the activity pursued at the destination reached. Based on this kind of statistical data, many national and international studies and reports have provided abundant information not only on traffic flow of vehicles and travel patterns of the entire mobile population, but also on older adults' actual travel behavior and its sociodemographic background conditions.

To summarize the findings, in general – albeit to a diverging extent depending on national levels of motorization – travel of older adults has clearly increased for about two decades. Among the older population, older men make more trips per day and travel more miles than older women; individuals with a driver's

license and access to a private automobile travel more than those who do not have a car at their disposal; and the older they are, the more people tend to decrease traveling, mainly due to increasing health and sensory impairments. Older women of the present generation have less education and a lower income, and less frequently possess a driving license, than men of the same age. These conditions can to a great extent explain why they stay closer to home and use public transportation more than men. This may change, however, when new cohorts of women reach retirement age for whom driving a car for getting around has become a matter of course, as it is the case today for most older men.

For some years now, this functional approach to mobility has become more and more questioned. To better understand actual travel-related choices, the focus has shifted to more activity-based and process-oriented models of travel and driving behavior. These approaches usually focus on the population as a whole, which consists predominantly of commuting working-age people. Therefore, even such advanced approaches do not seem adequate to capture the key concerns and various aspects of older adults' mobility. Trip chains composed of several modes are mostly judged by the main mode only, resulting in an underestimation of small trips and non-motorized means of locomotion, that is, older adults' most common travel modes, at least in Europe. Activities that might be subjectively significant, but that are pursued only once or twice a year, risk being neglected in studies limited to 1- or 2-day diaries.

Most of all, however, mobility comprises more than the functional aspects of getting from place A to destination B under certain conditions. Mobility can be performed for its own sake and not just as a derived demand. Moreover, in modern society, mobility – the ability to travel – is associated with highly valuated societal goals such as freedom, autonomy, and flexibility. The assessment of mobility should therefore include as much as possible of these aspects. The automobile, in particular, symbolizes such modern values, and among the whole range of currently available transportation modes, it opens up the most independent and flexible options for moving about.

Travel Patterns As has been reported repeatedly, the vast majority of older adults in the United States, but increasingly also in Europe, are largely dependent upon access to private automobiles. There is no cohort of older Americans that takes fewer than eight out of ten trips in a car.

In Europe, elderly people – at least currently – are far less 'auto-mobile' than in the United States. They make significantly fewer trips per day and travel fewer miles than comparable American elders. Currently, walking is clearly the most common travel mode of older Europeans. Almost half of all trips made by the people who participated in a study comparing the mobility needs and patterns of older adults in five European countries (Finland, Germany, Hungary, Italy, and the Netherlands) were on foot (45%). The car, used as driver (28%) or as a passenger (11%), was the second most important mode, with altogether usage by 39%; public transport including all modes (bus, tram, train, taxi, and special transport) was used in 8% and the bicycle in 10% of the trips. However, an area's provision with public transportation systems, the topographical conditions, and the availability of a car in one's household clearly affect older adults' choices of transport modes: In the German cities with relatively good public transport options, for instance, 54% of all trips are made on foot, and cars are used for only about 32% of all trips, whereas in the Finnish and Italian rural areas, the percentage of trips taken on foot barely amounts to one-third. In Italy, using the car (as a driver or passenger) is even more common than walking. The bicycle is used most often (up to 20%) in regions with favorable topographical conditions such as the flat Finnish, Hungarian, Dutch, and eastern German rural areas included in the study.

Older adults who are able to drive and actually use a private automobile are by far more satisfied with their general mobility than those without access to a car or who use cars as passengers only. When the impact of individual predictor variables on mobility satisfaction was examined, a clear and consistent pattern was observed: fair or good physical mobility, the ability to drive (and not just to have a car available), and being satisfied with the local public transportation system were found to be the most important variables in almost all regions studied. Only in Hungary did the availability and use of an automobile have no impact on satisfaction with mobility at all.

These results demonstrate that, in addition to good health and the capability to drive, good and accessible public transit can be crucial for satisfactory mobility. But often, the alternatives currently offered by conventional public transportation systems – if they exist at all – do not meet older people's need for mobility. In the United States, just 2.3% of older people use public transit for making trips. While in urban areas this figure amounts to 8.2%, it reaches only 0.3% in rural areas where transportation alternatives to the car are even less available.

Driving and Safety Issues The share of pensioner households that own a car still varies greatly. In the United States, it depends largely on income, gender,

family size, and ethnicity. In Europe, car ownership depends on the size of household, age, gender, income, and the country somebody is living in. This relation will change in both the United States and Europe in the coming years when the growing number of license holders who are used to relying on a car for conducting an active and mobile life style – in no small part consisting of women making up mobilization – reaches retirement age. Thus, travel trends in Europe are moving in the same direction as in the United States.

For about two decades now, the driving behavior and safety of the increasing number of old and very old traffic participants have been given great attention. The focus has been on assessing and improving the safety of older drivers and on driving problems, in particular those that are caused by chronic illnesses, sensory and mobility decrements, or dementia.

It is true that older drivers do not have a disproportionately greater frequency of involvement in accidents than younger drivers. As a person ages, though, the risk of his or her having an accident grows in relation to driving performance (and hence in relation to the exposure to danger), and when an older individual experiences an accident, the consequences are more severe than among younger adults. Walking or biking are not good alternatives either: elderly people are also very vulnerable as unprotected road users. Hence, helping older adults continue to drive safer has become a dominant goal in policy and practice. Activities include finding ways to screen and identify unsafe drivers, develop adequate education programs, and weigh different relicensing standards. Further efforts concern vehicle redesign and adaptation to older drivers' capacities as well as respective roadway improvements as compiled in, e.g., the Federal Highway Administration's *Highway Design Handbook for Older Drivers and Pedestrians*.

The Psychology Perspective

Psychological aspects have only recently received some attention in assessing and understanding older persons' mobility and flexibility. Motivational, cognitive, or personality aspects can, however, play an important role in their decisions about going out. For example, outdoor orientation, wayfinding, the use of automatic ticket dispensers, and the interpretation of mobility-related information depend strongly on cognitive abilities. At the same time, the experience of being in control over one's life circumstances and a high motivation for being on the go may motivate an aging individual to invest time and effort in maintaining a maximum level of out-of-home mobility even when confronted with functional or mental health decrements and/or adverse environmental conditions.

A sense of optimism and positive expectations of life were found to constitute main building blocks for the transport dimension of older adults' perceptions of quality of life. Psychological variables also played a role for characterizing groups of older adults who differed in their out-of-home mobility patterns. Perceptual motor processing, working memory, or visuomotoric coordination, which has repeatedly been found to be a major indicator of basic cognitive functioning, clearly and consistently decreased from the highly mobile and satisfied to the almost immobile and dissatisfied group. In addition, external control beliefs (measured with the control beliefs questionnaire used in the Berlin Aging Study) increased, while individual importance attributed to being out (assessed using an 11-point rating scale [0–10], higher scores indicating higher importance) decreased substantially from the first to the last group. Even in severely vision-impaired elders, this outdoor motivation turned out to contribute to mobility in terms of out-of-home leisure activities, particularly in urban areas.

A further psychological aspect may be the cognitive and emotional benefits conveyed by different options of performing mobility. In a comparison of private car users with users of public transportation, access to a car and, in particular, being a car driver appeared to confer more psychological benefits such as autonomy, self-esteem, and mastery than using public transport. This proved true independent of age, gender, or social class. Among men, in particular, driving and the type of car were associated with self esteem and prestige, while women appeared to gain more mastery and protection from car access, reflecting differing significance of cars in men's and women's lives. Similarly, besides instrumental functions, car use fulfills important symbolic and affective functions.

Altogether, these findings suggest that although physical, social, and technical resources, as well as the structural resources provided by a region or locality, constitute basic preconditions for moving about, they appear to be mediated by individual needs and emotions and by the subjective assessment of situations and one's own abilities.

Future Challenges and Perspectives

In the face of the acute demographic change, accompanied by a perpetually increasing proportion of older drivers in almost all industrial countries of the Western world, the related growth in driving and subsequent growth in traffic volume and congestion

have become an issue of general concern. At the same time, attention has been turning to the challenges that more and more older men and women face when they are no longer able to drive. Several studies showed that social isolation and depressive symptoms may increase when people are unable to get to shops and recreational facilities and stay connected with friends and community.

Both of these issues are particularly salient, as older adults in the United States, but increasingly also in Europe, are highly dependent on the car to obtain the mobility necessary for maintaining an independent lifestyle and active participation in society. Therefore, manifold efforts are undertaken to meet the diverse transportation needs of the growing older population and, on the one hand, to secure safe mobility for a maturing society, and on the other, to promote safe and sustainable environments. Among the strategies are driver programs; improving routes and highways; promoting attractive, accessible, and flexible public transit; developing alternative transportation options; creating pedestrian-friendly zones, walkways, and altogether livable communities; and suggesting policy agendas.

Of particular relevance are technological advances at various levels that can further support older adults' mobility needs. Improvements in road transport informatics and in-vehicle technologies promise to facilitate travel and improve safety for everyone and for older drivers, in particular. Automobiles can be redesigned to better fit older drivers' capabilities by a variety of cutting-edge technologies that include, for instance, vision systems, emergency systems, cruise control, stop and go assistance, parking assistance, collision avoidance systems, and curve lighting with global positioning systems (GPS). There are clear benefits for older drivers from road transport informatics and advance information on routes and travel times as well. However, all these devices and appliances still need further improvement. Due to limited information-processing capacity, assistive devices and telematic systems might overload older drivers by requiring continuous monitoring. The application of acoustic warning methods is limited because the ability to understand speech information at a low signal-to-noise ratio declines with advancing age.

Not least because of these developments that are suited to amplify driving options, the current generation and the generations of people to come will increasingly rely on the automobile. As a private and flexible means of transport, the car will not decline in importance, specifically for older people with an impaired ability to walk, especially those living in rural areas and suburbs with reduced local public transport service – at least not until mass transit systems begin to approach the flexibility and convenience of motoring about in an automobile. Aside from this, car use has been shown to be associated with symbolic functions, emotional benefits, and important societal values.

The greater availability of private cars and technological advances may expand older adults' scope of movement and action. At the same time, the growing volume and density of traffic that result also increase the potential hazards of such travel. Traffic congestion, particularly in urban centers, has reached an extent that may unsettle elderly people and keep them from venturing out. In several European studies, the perceived speed and volume of traffic has emerged as the key issue in the local area and in moving around in general. Therefore, the question of whether and how external conditions and demands of the environment can be harmonized with individual needs and resources will be a societal and political topic in the years to come.

Toward a More Holistic Concept of Older Adults' Mobility

The various perspectives on older adults' mobility presented here have shown the great variety of biological, social, environmental, psychological, and technological aspects that come together with this complex phenomenon. Some of them – for instance, the health perspective and the transportation and technology perspectives – have already contributed rich theoretical and empirical material for understanding older adults' physical, sensory, and cognitive preconditions for moving, and for describing – and, to some extent, explaining – their actual travel behavior.

However, our knowledge about some further aspects, both on the micro- and macro-levels and the interaction between the two, is still limited. Older adults' physical, social, and technical resources, as well as the structural resources provided in a region or locality, constitute only the basic preconditions for moving about. Equally important are, on the micro-level, their motives for traveling, the importance they assign to going out, their emotions and beliefs, and the experiences made when venturing out, all of which may influence their mobility in a variety of ways.

Examining characteristic connections between health, sociodemographic, psychological, and structural variables, on the one hand, and mobility measured in terms of actual trips made, modes of transportation used, and activities performed, on the other, points to clearly distinguishable subgroups of older adults who differ in their mobility options and behavior. The scope comprises the whole range between those who are well able to realize their

mobility needs and those who are at risk to become or already are completely immobile due to health decrements and/or who are lacking support and quality of the local community.

On the macro-level, there are not only population density and land use, types of settlements and institutional arrangements, welfare regimes, driver license regulations, and transport management that affect older adults' options for moving about, getting places, and staying connected with their social communities and physical environment, but also a society's level of modernization and mechanization, cultural traditions, habits, and values. These aspects and their interaction with micro-level aspects have largely been neglected in previous research.

Hence, compiling sociological, behavioral, physiological, and transportation research and urban planning can provide deeper insights for understanding older adults' concerns about mobility and developing strategies that are suited to meet their respective needs.

See also: Disability, Functional Status and Activities of Daily Living; Driving Behavior; Environmental Gerontology; Human Factors Engineering and Ergonomics; Social Networks, Support, and Integration.

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Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts

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Glossary

Allele – An alternate form of a gene.

Epistasis – An interaction between genes in which the action of one gene masks that of another.

Eukaryote – An organism whose cellular DNA is in a nucleus.

Gene – A unit of genetic information.

Genome – All of the genetic material of an organism.

Longevity-Assurance Gene – A gene that sets the limit (upper and/or lower) for longevity of an organism.

Mitochondrial DNA – The DNA containing the genome of the ATP-generating organelle of the cell, the mitochondrion.

Mutant – A member of a species carrying an alteration (mutation) in one or more genes.

Phenotype – The entire set of physical characteristics of an organism.

Introduction

The major invertebrate models in aging research are the nematode worm *Caenorhabditis elegans* and the fruit fly *Drosophila melanogaster*. Early studies in which fruit flies were selected for late reproduction over several generations, resulting in strains that displayed extended longevity, cemented the role of genes in determining life span. The isolation of the *age-1* mutant in the worm, which enhanced longevity, further bolstered this role. Since then, some 60 worm genes that affect life span, belonging primarily to two groups, have been identified. The list is considerably smaller in the fruit fly, overlapping one of these two groups.

Invertebrates

Age Changes

Life span in worms and flies is measured chronologically as the time from emergence of the adult form to death. Reproduction occupies only a fraction of the adult life span in the worm, while in the fly it continues until close to the end. In both animals, aging is accompanied by a variety of changes. The loss of mobility is seen readily, as is the accumulation of age pigments. There is also an accumulation of oxidative stress and induction of antioxidant enzymes. Some evidence for genome instability has been gathered in the worm in the form of transposon Tc1 mobilization with age. Declining mitochondrial function has also been seen during aging. In the worm, extended longevity is associated with metabolic changes that can readily balance declining mitochondrial function, because they include activation of the glyoxylate cycle (about which more will be said in the discussion of yeast aging later). This suggests that extended longevity is fundamentally a metabolic mechanism. Further support for this notion comes from the fact that extended longevity is associated with fat and glycogen storage.

A systematic study of the tissue pathology of aging has been carried out in the nematode. This analysis showed a wide array of changes that proceed to a different extent in different individuals. These changes are profound, and they essentially portray a gradual dissolution of tissue structure and hence of function.

Metabolic rate has been studied in both worms and fruit flies as a function of age. An analysis of the rate of living theory of aging has been carried out based on such studies using strains that have different life spans. It is difficult to generalize from this effort and determine whether the theory is correct, as there is evidence both for and against it. A major difficulty in interpretation is the fact that metabolic rate is measured by oxygen consumption and carbon dioxide production. The determination of metabolic rate from these measures rests on certain assumptions regarding the nature of the metabolism, which may be quite different in the various conditions. For example, utilization of the glyoxylate cycle would significantly lower the carbon dioxide produced given the same oxygen consumption, as glyoxylate cycle utilization is more economical.

Environmental Effects on Life Span

Calorie Restriction Calorie restriction increases life span in both worms and flies. The difficulty in equating this phenomenon with that described in rodents is that it has not actually been demonstrated that the animals eat less, especially on an individual basis. That is, the food concentration is lowered or the calorie source changed in the medium, but the

actual food consumption is not measured. At least two studies demonstrated that the food composition plays an important role in fruit flies, not simply total calories. This also distinguishes the so-called calorie restriction in vertebrate and invertebrate species.

There is another difference between calorie restriction in fruit flies and in mice. In fruit flies, the calorie restriction appears to operate by the insulin/IGF-1 pathway, while in mice, calorie restriction and the IGF-1 pathway appear to be distinct. The latter may also be the case in the worm. This discrepancy may be due to the fact that calorie restriction in mice and in invertebrates is not the same phenomenon. In the invertebrates, it may be purely a nutrient signaling phenomenon, while in mice it may entail more than that. This issue is discussed further in the section on yeast.

In the worm, there is a form of calorie restriction that is imposed genetically. The worm *eat* mutants have a defective pharynx and have difficulty consuming bacteria; they are actually starved rather than calorie restricted. Nevertheless, this treatment can extend their life span. Knockdown of the target of rapamycin (TOR) pathway in the worm extends life span, reflecting the role of nutrient sensing in determining longevity.

Heat Stress Sublethal heat shock extends the life span of both worms and fruit flies. In the worm, heat shock induces hsp16, and it is this heat shock protein that is required for life extension. In fact, overexpression of hsp16 can extend worm longevity without heat shock. In the fruit fly, it is the hsp70 homologue that is essential for life extension. Additional copies of the gene generate a greater life extension on administration of the heat stress.

Long-lived strains of the nematode show resistance to heat shock, oxidative stress, and ultraviolet radiation. This multiple stress resistance requires the activity of the DAF-16 forkhead transcription factor that is required for life extension by at least one of the mechanisms of extended longevity. This suggests that extended longevity is a stress resistance phenomenon. Overexpression of copper, zinc-superoxide dismutase in the fruit fly extends its life span, supporting this view.

Mechanisms of Aging

Caenorhabditis elegans Several different mechanisms by which life span can be extended in the worm have been differentiated, although they may not all be completely distinct. The first and most prominent mechanism into which most of the others seem to feed is the dauer or *daf* signaling pathway (**Figure 1**). This pathway is of significant interest because it is conserved in many of its features from the worm to the fruit fly to the mouse.

The nematode has numerous potential ligands for a single insulin/IGF-1-like receptor encoded by *daf-2*. Binding of at least one of these, which can be replaced by human insulin, activates the DAF-2 signaling pathway. An activated DAF-2 transmits the signal to phosphatidylinositol 3-hydroxyl kinase (PI3 K), one of whose subunits is encoded by the *age-1* gene. The signal is relayed to protein kinase B (Akt) through a phosphatidylinositol-dependent protein kinase (PDK). Phosphorylation of the forkhead transcription factor DAF-16 by protein kinase B prevents its translocation into the nucleus and activation of the target genes. Thus, abrogation of DAF-2 signaling extends life span, and this is prevented by deletion of *daf-16*. The *old-1* gene encodes a tyrosine kinase receptor, whose expression is under the control of DAF-16 and which impinges upon the DAF-16 pathway.

There is some controversy as to the critical site or tissue in which DAF-16 signaling is important for life extension. Clearly, signaling in the nervous tissue is important. In particular, the neuroendocrine system with the chemosensory amphid neurons that signal the presence of food is involved, as their ablation extends longevity. However, there is evidence that the endoderm or gut also plays a role. Since the latter tissue is the site of lipid storage, it would be a likely target of signaling, and the activation of the glyoxylate cycle in *daf-2* mutant worms makes sense because this metabolic pathway allows the worm to use fat as a source of energy and for the synthesis of protein and carbohydrate.

There is a complex interaction between the DAF-16 pathway and the somatic and germline gonads that involves signaling through the DAF-12 transcription factor. DAF-12 belongs to the thyroid hormone/steroid hormone/retinoic acid receptor superfamily. Ablation of the germline gonad extends life span on its own.

Mitochondria have been demonstrated to play an essential role in determining life span in *C. elegans*. The first indication came from implication of the *clk-1* gene in life span determination. This gene impacts timing in the life cycle of the worm and affects its bioenergetics. It is a homologue of the yeast *COQ7* gene, which is involved in ubiquinone synthesis. Ubiquinone is a lipid-soluble electron carrier in the mitochondrial respiratory chain. Indeed, provision of ubiquinone in the medium allows the *clk-1* mutant worm to grow. Interestingly, limitation of ubiquinone in the diet can extend life span independent of

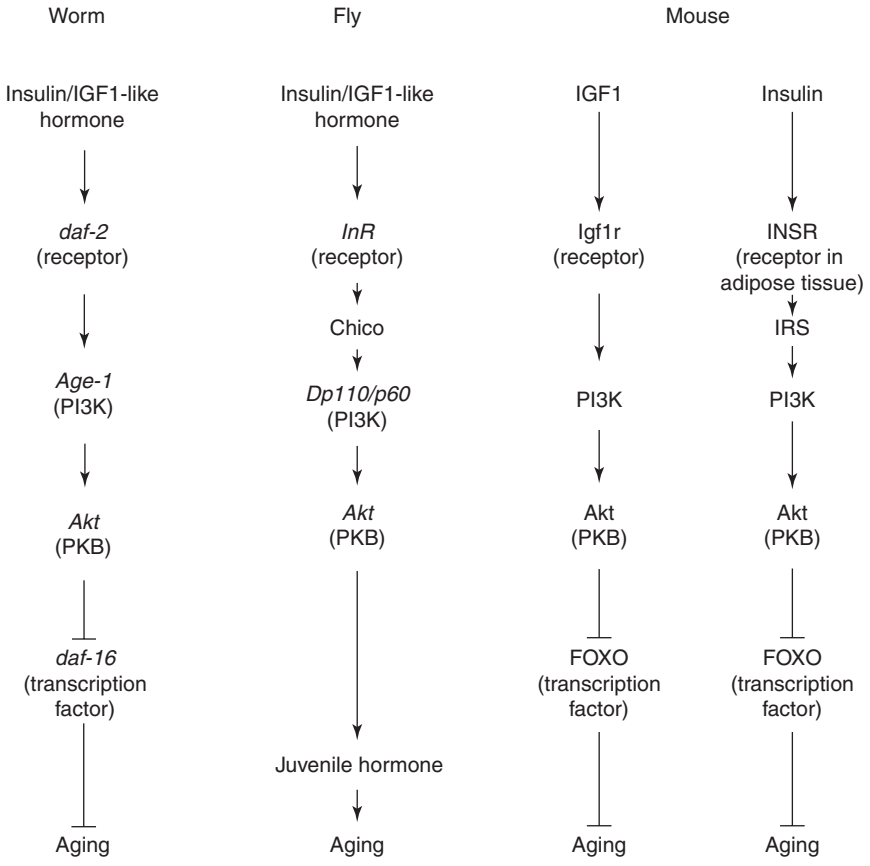

Figure 1 The insulin/IGF-1 signaling pathway is conserved in metazoans. In invertebrates such as *C. elegans* (worm) and *D. melanogaster* (fly), hormones related to insulin and IGF-1 bind to their cognate receptors initiating a signal transduction pathway, which includes a phosphatidylinositol 3-OH kinase (PI3K), and a protein kinase B (PKB) known as Akt. Among the downstream targets are transcription factors belonging to the forkhead family (DAF-16 and FOXO). The result of the activation of this pathway is a curtailed life span. In mammals, there is an IGF-1 pathway that is separate from the insulin pathway. Activation of these pathways in mice, in the case of adipose tissue for insulin, favors aging. In both the fly and the mouse insulin pathway, an insulin receptor substrate (Chico or IRS) is interposed between the receptor and PI3K. Pointed arrows, stimulation; blunt arrows, inhibition.

the *daf-2* pathway. This may lead to the activation of fumarate reductase, an alternative oxidase, which functions in the electron transport chain of these worms. Fumarate reductase is known to be induced in dauer worms, a long-lived larval form that can be induced by mutation of *daf-2*. These effects on worm longevity are reminiscent of the retrograde response (discussed later), which extends life span in filamentous fungi and yeasts.

A genome-wide as well as directed RNA interference (RNAi) screen has shown that knockdown of genes encoding mitochondrial proteins extends life span. The resulting mitochondrial dysfunction is likely to activate compensatory changes in gene expression. The results provide strong support for a life-extending retrograde response in the worm. It has been shown that RNAi knockdown of the worm frataxin gene, which encodes a protein that transports iron into mitochondria, extends life span.

Drosophila melanogaster Studies in *D. melanogaster* confirm the importance of insulin/IGF-1-like signaling for longevity. Mutants in the fruit fly insulin receptor yield dwarf animals that display extended longevity. Mutants in the fly homologue of the insulin receptor substrate, *chico*, exert similar effects. These studies also point to the importance of the neuroendocrine system in aging, because a downstream target of the insulin/IGF-1-like receptor pathway is the juvenile hormone.

Fruit fly mutants have been screened for extended longevity. This yielded the *methuselah* mutant, which displays increased resistance to thermal and oxidative stress and to starvation. This gene encodes a transmembrane receptor kinase. One of the first longevity mutants in the fruit fly was *indy*. This gene encodes a dicarboxylic acid transporter, and the effect of this mutation has been interpreted as being similar to calorie restriction – an intriguing possibility that is highly cogent to the entire problem of

nutritional effects on longevity. Finally, it has been convincingly shown that the deletion of the fly *rpd3* histone deacetylase homologue extends life span. As in yeast, this effect is due to an overlap with calorie restriction. In the fruit fly, this effect is due to the derepression of the *sir2* gene. This is different from the corresponding effect in yeast. Nevertheless, the results indicate that the Rpd3 histone deacetylase is a master regulator of life span in diverse models of aging.

Filamentous Fungi

Several filamentous fungi have been studied as models of aging. Among these, *Podospora anserina* and various species of *Neurospora* have been examined extensively, and an understanding of the causes of aging in these organisms has developed. Life span in these fungi is measured by total reproductive output. It is measured by the length of the mycelium before it senesces and dies; it can also be measured as the time between inception of mycelial growth and its cessation. The reproductive effort involved is the extension of the mycelium by the directional production of new cells, one after another. Senescence is marked by slowed growth, difficulty in aerial hyphae production, and increased pigmentation.

The etiology of aging is clearly mitochondrial in filamentous fungi. Aging is associated with instability of the mitochondrial genome, whose causes differ in *P. anserina* and in *Neurospora*. In *P. anserina*, various portions of the mitochondrial genome can excise as the organism becomes older. These DNAs are circular and amplify. They are recombinogenic, causing further rearrangements in the mitochondrial genome with the loss of sequences essential for respiratory function. In *Neurospora*, some strains possess indigenous, linear plasmids in their mitochondria. These plasmids can integrate into the mitochondrial DNA, inactivating target genes and causing DNA instability. The inactivation of mitochondrial energy production is lethal in filamentous fungi, which are obligate aerobes.

Senescence has been subjected to genetic dissection in filamentous fungi. Due to the more advanced state of the field, the work on *P. anserina* senescence is discussed here. The genes identified are encoded by the nuclear as well as the mitochondrial genomes. The work has been followed up with a molecular dissection of the aging mechanisms involved, resulting in a rather sophisticated understanding of the role of two of the genes in aging in this fungus. Not surprisingly, these studies revolve around mitochondrial function.

Mechanisms of Aging

Alternative Oxidase and Reactive Oxygen Species *Grisea* is a nuclear gene that encodes a transcription factor that is active at low copper levels. Under these conditions, it induces the expression of a high-affinity copper transporter and manganese superoxide dismutase and additional genes as well. The import of copper into the cell is essential for the assembly of complex IV (cytochrome oxidase) of the mitochondrial electron transport chain. Thus, the loss of *Grisea* should result in lethality, because *P. anserina* is an obligate aerobe. It does slow down growth, likely due to lower ATP production, but the fungus lives about 60% longer. The resolution of this dilemma comes from the induction of an iron-dependent alternative oxidase, which accepts electrons from ubiquinone, leaving only complex I (NADH:ubiquinone oxidoreductase) to generate an electron motive force.

The generation of reactive oxygen species is much lower when the fungus respires using the alternative oxidase as compared to cytochrome oxidase. This strongly suggests that an important reason for the longer life span of the *grisea* mutant is a decrease in oxidative stress generated by mitochondria. However, there is also a complete absence of the mitochondrial DNA rearrangements and deletions, and production of circular DNAs, in this mutant. Excess copper in the growth medium reverts this phenotype, indicating that the recombination involved in these rearrangements is copper dependent. The fact that the *grisea* mutant ages, albeit with a delay, in the absence of accumulation of circular DNAs derived from the mitochondrial genome indicates that these are not the cause of senescence. This point is also supported by cytoplasmic ribosome mutations that prevent the appearance of these circular DNAs yet do not prevent senescence.

There is still some cytochrome oxidase activity in the *grisea* mutant due to a low amount of copper uptake by a low-affinity transport system. This may lead to some reactive oxygen species production through a diminished activity of the standard electron transport chain. This may be the cause of the limited, if longer, life span of the mutant. Because GRISEA also transcribes the mitochondrial manganese superoxide dismutase, the damaging effect of this residual production of reactive oxygen species would be amplified, as superoxide dismutase removes certain of these damaging molecules. This effect would be further exacerbated by the reduced activity of cytoplasmic copper, zinc-superoxide dismutase, which requires copper for activity.

In the ex1 mutant, the alternative oxidase is also induced. This mutant has a deletion of large parts of

the *CoxI* gene, which encodes the largest subunit of cytochrome oxidase in the mitochondrial genome; consequently, it is completely devoid of standard electron transport chain activity. This makes ex1 entirely dependent on the alternative oxidase for survival, and it dramatically reduces production of reactive oxygen species. The ex1 mutant is immortal in keeping with the interpretation that it is oxidative damage to mitochondria that is the cause of senescence in *P. anserina*.

A Retrograde Response in Podospora? In *Saccharomyces cerevisiae,* mitochondrial dysfunction signals a program of nuclear gene expression changes that compensate, resulting in life extension. The *grisea* and ex1 mutants conjure up something akin to this retrograde response. The question is whether this represents a normal physiological process during aging of the fungus. The senescent phenotype makes its presence known at the tips of the growing hyphae in the mycelium, where growth requires substantial energy production. This is where oxidative damage and mitochondrial DNA instability evolve during aging. Replacement of damaged mitochondrial material by functional components requires the concerted action of both mitochondrial and nuclear DNA. Once the capacity for replacement is overwhelmed, the only recourse prior to senescence would be the activation of alternative oxidase in a retrograde response. It will be of interest to determine whether alternative oxidase is indeed induced prior to senescence.

There are several observations consistent with the interpretation that mitochondrial deficits result in activation of a retrograde response with attendant life extension. A long-lived nuclear mutant that encodes the PaTOM70 protein of the mitochondrial protein import apparatus has been isolated. In this case, a deficiency in the assembly of active mitochondria would activate the retrograde response and extend life span. It has also been argued that certain nuclear gene mutations, such as in the protein translation factor eEF-1α, that alter translation accuracy extend life span by altering the mitochondrial protein profile. Such changes could well induce a retrograde response.

It is interesting to recall early studies that demonstrated the life-extending effect of various inhibitors of mitochondrial metabolism provided at doses below a growth-inhibitory threshold. These inhibitors included inhibitors of mitochondrial ribosomes, compounds that intercalate into mitochondrial DNA, and respiratory poisons. The effects closely resemble those that activate the well-characterized retrograde response in yeast.

Yeast

Phenomenology of Aging

Longevity and aging have been studied in the budding yeast *S. cerevisiae* and in the fission yeast *Schizosaccharomyces pombe*. However, the investigations in the latter species include only one publication describing the phenomenon of limited replicative capacity. Thus, this discussion is confined to budding yeast, simply called yeast from this point on. The first and most extensively studied form of aging in this organism is the replicative life span, defined as the limited capacity of an individual cell to continue dividing or producing daughter cells. In the 2000s, several reports pertaining to the chronological life span of yeast have appeared. Chronological life span is defined as the time spent in a non-dividing or stationary phase before the ability to produce progeny is lost. Replicative life span is an individually measured trait, while chronological life span is determined for a yeast culture or population. Not all yeast cells stop metabolizing immediately after their last division, so the notion of a postreplicative life span should be entertained. There is clearly a negative impact of chronological aging on the replicative life span of cells emerging from stationary cultures.

The mortality rate of dividing yeast cells can be expressed as a function of replicative age. This mortality rate increases exponentially with a plateau at later ages, such that the last 10% of the surviving population shows no further increase in mortality rate. For chronological aging, mortality rate fluctuates dramatically, but this may not be due simply to regrowth of the culture from the surviving cells. A multitude of changes has been described in yeasts progressing through their replicative life span. These changes have been seen at the cellular, subcellular, physiologic, and molecular levels; many of these changes describe a loss of function. Thus, it is possible to speak of aging of replicating yeasts. The changes that have been identified in yeasts aging chronologically are much less numerous. The mode of death of replicating and chronologically aging yeasts, as described by a few studies, appears to be apoptotic by several of the standard criteria applied to animal cells. There is some evidence that this apoptosis represents 'altruistic' behavior on the part of the dying cells, which in the process provide nutrients for the survivors.

A mathematical model of an aging system has been formulated that predicts a stratification of an aging population due to change in the individual aging organism. This model is applicable not only to the organism but also to lower levels of biological organization, down to the molecular. Several predictions of

this model have been met by yeast cells. By extension, random age changes must have predictive value with regard to the longevity of the individual. Indeed, this was shown to be the case when the random changes in budding patterns of individual yeast cells were examined during the replicative life span. Thus, the role of chance in aging has been subjected to experimental analysis in yeast.

Most of the work on replicative life span has dealt with the question of what determines the aging of the mother cell. However, a full understanding of the yeast replicative life span requires an assessment of the factors that determine why a daughter is born young and has before it the potential for a full replicative life span. Evidence for a senescence factor that accumulates in mother cells and only 'leaks' into daughter cells produced by very old mothers was obtained early on. Furthermore, it has been demonstrated that the daughters of older mothers have a shorter life span than those produced by young mothers, providing additional support for the existence of the senescence factor. The fact that daughters are born young during most of the life span of the mother cell is a manifestation of age asymmetry between mother and daughter.

Genetic Determinants of Longevity

Numerous genes impact the replicative life span of yeast, while fewer have been demonstrated to have this effect on chronological life span (**Table 1**). There is some overlap between these two gene sets. It is evident that the more numerous genes that determine replicative life span encode a wide range of biochemical functions. However, these functions fall into four obvious categories: metabolism, stress resistance, chromatin-dependent gene regulation, and genome stability. Of course, there is always the omnibus category of other. This breakdown coincides with those categories important in other genetic model systems of aging, both invertebrate and vertebrate.

Most of the genes alluded to previously were discovered by testing specific hypotheses about the mechanisms underlying yeast aging, using a reverse genetic approach. A few were identified by either examining a presumed surrogate phenotype associated with longevity or screening for genes that were differentially expressed during the yeast replicative life span. No one thus far has attempted a direct screen for mutants in genes that affect life span in yeast. However, a screen for genes that affect longevity has been carried out on a genome-wide collection of gene deletion mutants. At present, only two yeast longevity genes possess orthologues that have been shown to affect the life span of higher organisms, *C. elegans* and *D. melanogaster*: the genes encoding the silent information repressor complex component Sir2 protein and the yeast protein kinase B (Akt) Sch9 protein. Overexpression of Sir2 protein extends replicative life span, although not in some studies. Sch9 protein has the distinction of affecting both replicative and chronological life span.

Environmental Effects on Life Span

Calorie Restriction Three environmental manipulations have been used to alter yeast life span. The most heavily analyzed is nutrient limitation, which has been given the misleading name of calorie restriction. In this paradigm, the concentration of a nutrient, usually glucose, is changed in the growth medium and the effect on life span is determined. Although the concentration of the nutrient is lowered, it is provided without any curbs. Sir2 protein in yeast appears by some accounts to function in life extension induced by nutrient limitation, although at least two studies dispute this interpretation. Polyphenols, such as resveratrol, extend yeast life span by activating the NAD-dependent protein deacetylase activity of Sir2 protein, which in yeasts appears to be directed at acetyl groups in histones. However, resveratrol did not affect a true protein deacetylation reaction in another study; it did not extend life span in that study either. The significance of the positive effects of resveratrol resides in its reputed role as a calorie restriction mimetic in yeast. The ambiguities raise the possibility that resveratrol may be acting primarily as an antioxidant in yeast.

Deletion of the glucose sensor gene, *GPR1*, extends replicative life span. The signaling pathway in which Gpr1 protein functions has been described. The results indicate that glucose curtails yeast longevity through a signaling pathway whose downstream target is protein kinase A (cyclic AMP-dependent protein kinase), whose negative effects on yeast longevity have been known for quite some time. Thus, so-called calorie restriction in yeast may actually be more of a signaling phenomenon. This conclusion, however, requires a demonstration that glucose limitation and Gpr1 protein function are coextant in determining yeast replicative life span.

Oxidative Stress Pro-oxidants such as paraquat curtail yeast replicative life span; this effect also pertains to hydrogen peroxide. The negative effect of hydrogen peroxide on life span can be reversed by the antioxidant glutathione. Oxidative stress increases with age. All of these findings suggest that oxidative stress is a life span-limiting factor in yeast.

Table 1 Yeast longevity genes

Gene	*Function*	*Category*
Replicative aging		
LAG1	Ceramide synthesis	Stress resistance
LAC1	Homologue of *LAG1*; ceramide synthesis	Stress resistance
RAS1	GTP-binding (G-) protein, signal transduction	Stress resistance
RAS2	G-protein, signal transduction	Metabolism, stress resistance
CDC35	Adenylate cyclase (also called *CYR1*)	Metabolism, stress resistance
BCY1	Regulatory subunit of protein kinase A	Metabolism, stress resistance
PHB1	Membrane-bound, mitochondrial protein chaperone	Metabolism, stress resistance
PHB2	Homologue of *PHB1*; chaperone	Metabolism, stress resistance
CDC7	Protein kinase; cell cycle control	Other
BUD1	G-protein; cell polarity	Other
RTG2	Unknown; retrograde response	Metabolism, genome stability
RTG3	Transcription factor	Metabolism, stress resistance
RPD3	Histone deacetylase; transcription	Chromatin-dependent control
HDA1	Histone deacetylase; transcription	Chromatin-dependent control
SIR2	Histone deacetylase; transcriptional silencing	Genome stability
SIR4	Transcriptional silencing	Chromatin-dependent control
UTH1	Mitochondrial biogenesis	Metabolism
UTH4	Unknown	Other
YGL023	Homologue of *UTH4*	Other
SGS1	DNA helicase; DNA recombination	Genome stability
RAD52	DNA repair	Genome stability
FOB1	Replication fork block protein	Genome stability
CDC25	GDP–GTP exchange factor for Ras proteins	Stress resistance
TPK2	Protein kinase A catalytic subunit	Metabolism, stress resistance
GPR1	Plasma membrane glucose sensor	Metabolism
GPA2	G-protein	Metabolism
ZDS1	Transcriptional silencing	Chromatin-dependent control
ZDS2	Transcriptional silencing	Chromatin-dependent control
NMT1	N-myristoyltransferase	Other
SIP2	Unknown; N-myristoylprotein	Metabolism
SNF1	AMP-activated protein kinase homologue	Metabolism
SNF4	Regulatory subunit of Snf1 complex	Metabolism
SOD1	Copper, zinc-superoxide dismutase	Stress resistance
SOD2	Manganese-superoxide dismustase	Stress resistance
CTA1	Peroxisomal catalase	Stress resistance
CTT1	Cytoplasmic catalase	Stress resistance
NPT1	Nicotinamide phosphoribosyltransferase	Metabolism
PNC1	Nicotinamidase	Metabolism
SCH9	Protein kinase B (Akt) homologue	Metabolism, stress resistance
Chronological aging		
SCH9	Protein kinase B (Akt) homologue	Metabolism, stress resistance
CDC35	Adenylate cyclase (also called *CYR1*)	Metabolism, stress resistance
RIM15	Protein kinase	Stress resistance
MSN2	Transcription factor	Metabolism, stress resistance
MSN4	Transcription factor	Metabolism, stress resistance
RAS2	G-protein	Metabolism, stress resistance
SOD2	Copper, zinc-superoxide disumutase	Stress resistance

This view is bolstered by the negative effects on longevity of deletion of the catalase and superoxide dismutase genes.

Heat Stress The third environmental factor that has been shown to affect yeast replicative life span is heat stress. The effects of heat stress on longevity are complicated. Sublethal heat stress extends replicative life span. This effect is seen even when this stress is applied in several independent bouts. The life extension under these circumstances is due to a persistent, but not permanent, decline in mortality rate. However, there is a limit to the number of bouts of stress that can be applied to achieve an attendant increase in life span. Beyond that point, life span declines. The *RAS2* gene is essential for the cell to withstand chronic bouts of sublethal heat stress. Upon application of the stressor, a program of gene

expression changes is activated to protect the cell. In the absence of *RAS2*, these genes remain turned on for a long time even when the stress has long been absent. The protective effect of *RAS2* requires its capacity to activate adenylate cyclase and hence to induce the synthesis of cyclic AMP.

The life extension obtained on administration of a limited number of bouts of sublethal heat stress requires both *RAS1* and *RAS2*. The former has a peculiar role in supporting glucose-stimulated inositolphospholipid turnover. The *LAG1* gene, the first longevity gene identified in yeast, operates ceramide synthesis, which impacts resistance to heat stress. Interestingly, the dependence of life span on *LAG1* expression is bimodal, with an initial rise in life span on increased expression followed by a decline at higher levels of expression.

The deletion of *RAS2* increases chronological life span, which is undoubtedly the result of massive derepression of stress resistance genes. Cells in stationary culture must 'stay and fight' for the population to survive. This differs markedly from the situation in a replicating yeast culture, in which even rare survivors can restore the population. In the absence of overt stress, overexpression of *RAS2* extends replicative life span. This effect is due to the stimulation of a cyclic AMP-independent pathway. These effects of *RAS2* point to a recurring theme in aging. The effect of a manipulation on life span depends very much on the particular set of circumstances. The organism has evolved to adapt to a certain range of environmental conditions, leaving a narrow window in which life span can be optimized without compromising this adaptability. This is an example of a trade-off.

Mechanisms of Aging

Extrachromosomal Ribosomal DNA Circles Ribosomal DNA is present as a tandem array of between 100 and 200 repeats in yeast. This arrangement facilitates intramolecular recombination events to produce circular, episomal DNA species. It has long been known that these circles are at equilibrium with the chromosomal copies, expanding in number or contracting under various conditions. In some studies but not in others, the cellular content of these circles was suppressed by the Sir2 and Sgs1 proteins. The circle content increases with the replicative age of the cells. These studies formed the foundation for the claim that the major, if not sole, cause of aging in yeast is the ribosomal DNA circles and that the role of Sir2 protein in yeast longevity is based exclusively on its effect on circle formation. This interpretation of the role of Sir2 protein neglects its well-known action in silencing gene expression.

There is little doubt, however, that extrachromosomal ribosomal DNA circles contribute to yeast cell demise during the replicative life span. Deletion of the replication fork block gene *FOB1* completely eliminates the production of the circles and at the same time increases life span substantially. It has become clear in at least two studies that the formation of circles masks other mechanisms of replicative aging in yeast. Nevertheless, these circles underscore the role of nuclear genome instability in aging.

Interorganelle Signaling: The Retrograde Response Mitochondrial dysfunction in yeast signals a wide array of gene expression changes in the nucleus. These gene expression changes are confined to metabolic and stress response genes. The retrograde signaling pathway contains several signal transduction proteins that were discovered through its study, as well as many others known originally from other investigations. Ras2 protein and the target of rapamycin (TOR) complex modulate the retrograde response. Ras2 protein and TOR are both involved in sensing the intracellular status of yeasts, broadly defined as metabolic and stress state. Activation of the retrograde response extends yeast replicative life span (**Figure 2**). It is therefore not surprising that Ras2 protein affects yeast longevity; we expect that TOR does as well.

The activation of the retrograde response compensates for the loss of full mitochondrial function. The genes that are induced encode proteins destined for the cytoplasm, mitochondria, and peroxisomes. The metabolic changes that occur bolster the activity of part of the tricarboxylic acid cycle and provide other sources of biosynthetic intermediates with which this truncated cycle can cooperate, most notably the glyoxylate cycle. The glyoxylate cycle allows the yeast cell to use acetate to make carbohydrate and protein, because the two carbons of acetate are not lost as carbon dioxide as they are in the tricarboxylic acid cycle. This effect is reminiscent of the activation of the glyoxylate cycle in *C. elegans* strains that display extended longevity. As mentioned earlier, induced mitochondrial dysfunction in this worm extends its life span.

It is evident that the retrograde signaling pathway and the pathway that signals nutrient limitation in yeast are distinct. However, it is also clear that there is overlap between the two pathways in terms of their downstream effectors. The retrograde response compensates for mitochondrial dysfunction. On the other hand, calorie restriction augments the activity of this organelle in what appears to be a preventive mechanism. It is this effect of calorie restriction that is likely to result in life extension. Sir2 protein may

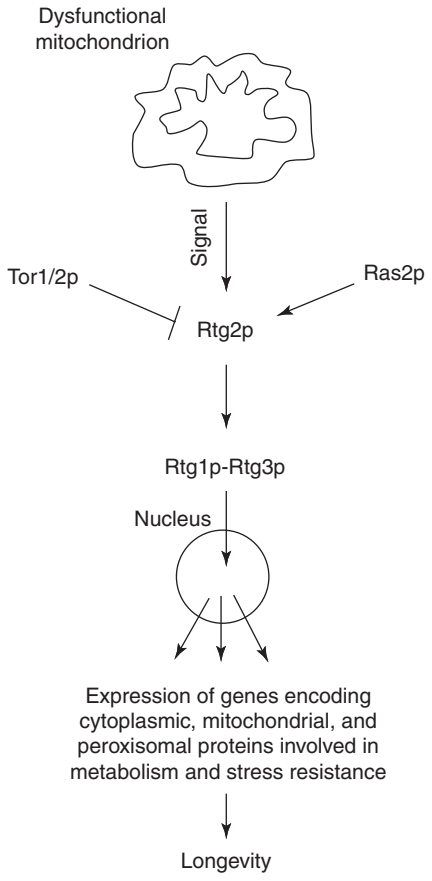

Figure 2 The retrograde response in yeast. Mitochondrial dysfunction elicits a signal that is relayed by the Rtg2p to the Rtg1p–Rtg3p transcription factor, which enters the nucleus and induces the expression of many genes encoding proteins destined for the cytoplasm, the mitochondria, and the peroxisomes. These proteins are involved in metabolism and stress resistance. This increases longevity. Ras2p and the TOR complex potentiates or represses the retrograde pathway, respectively.

respond to the metabolic state of the cell, because it requires the oxidized coenzyme NAD rather than reduced NADH for activity. However, some studies indicate that the NAD concentration changes that could regulate Sir2 protein function do not occur in cells. In addition, other studies argue that Sir2 protein is actually regulated by the levels of nicotinamide, an inhibitor of the enzyme, rather than by NAD. Given the available evidence, the most reasonable hypothesis is that Sir2 protein activity is a permissive factor in the effect of nutrients on yeast longevity in some cases but is not directly involved in signaling nutrient availability.

Activation of the retrograde response not only extends life span, but also postpones the manifestations of senescence. Studies demonstrating the role of the retrograde response in life extension involved experimental manipulation of yeasts to abrogate the activity of the electron transport chain. However, it has been shown that there is a decline in mitochondrial function with replicative age, which coincides with an increase in oxidative stress, and that this is associated with the induction of the retrograde response. It has also been found that the retrograde response titrates accumulating mitochondrial dysfunction, such that the greater the dysfunction, the greater its activation. Thus, this mechanism operates in normal yeast aging. In fact, it is the only such mechanism, because it fulfills four criteria: its activation extends life span, it postpones senescence, it impacts a normal aging process, and it is induced during the course of normal aging. Perhaps its activation is why yeasts live as long as they do.

There is a connection between the retrograde response and extrachromosomal ribosomal DNA circles. Activation of the response increases circle production. However, approximately one-half of the life extension effect of the retrograde response occurs through the amelioration of the deleterious effects of the circles. This explains why the retrograde response extends life span even in the face of circle accumulation. The retrograde signal transducer Rtg2 protein plays a pivotal role in circle formation. This protein suppresses genome instability, including the instability manifested by circle production. But it can only do so when it is not transmitting the retrograde signal from the mitochondrion. Thus, the mitochondrial dysfunction that activates the retrograde response harnesses Rtg2 protein, making it unavailable for maintenance of genome stability.

When the Rtg2 protein travels from the cytoplasm to the nucleus on sensing mitochondrial dysfunction, it becomes a component of the transcriptional coactivator complex called SLIK, for SAGA-like. In this complex, which contains the histone acetyltransferase Gcn5, Rtg2 protein participates in chromatin-dependent gene activation. The activity of SLIK is counteracted by the histone deacetylases Rpd3 and Hda1, whose deletion is known to increase longevity. Rtg2 protein in the SLIK complex links mitochondrial activity to chromatin-dependent gene activation, metabolism, and stress responses, and to genome stability. This dependence points to the primary role of metabolism, especially mitochondrial metabolism, in determining yeast life span.

Age Asymmetry A mutant that disrupts the age asymmetry between mother and daughter cells such that the daughters are born old was isolated. It is in the *ATP2* gene, which encodes the β-subunit of mitochondrial F_1-ATPase. The cell pathology that occurs in this mutant involves a gradual loss of mitochondrial membrane potential, abnormal

morphology and distribution of mitochondria, and gradual loss of segregation of active mitochondria to daughter cells. This is accompanied by clonal senescence, which is a population manifestation of the birth of daughter cells possessing the same replicative age as their mothers at the time of birth. Interestingly, the defects observed in this mutant also occur in normal mother cells as they get older, causing the 'leakage' of dysfunctional mitochondria to daughter cells. Thus, defective mitochondria appear to be the senescence factor described earlier. These results have led to the suggestion that, more generally, age asymmetry depends on the sequestration of damaged components within mother cells. It has been shown that oxidized proteins contained in mitochondria among others are indeed retained in mother cells, at least when they are young, and that this depends on the Sir2 protein. The mechanism by which Sir2 protein accomplishes this is not clear, but it is not likely to involve extrachromosomal ribosomal DNA circles.

The studies of age asymmetry point to another feature of mitochondrial function that is important in aging, namely, mitochondrial membrane potential. During aerobic metabolism, the electron transport chain is largely responsible for providing the force driving its generation. However, the F_1-ATPase, together with the ATP-ADP translocator, assumes this function in fermenting cells. Mitochondrial membrane potential plays an essential role in powering the transport of biosynthetic intermediates between the mitochondrial matrix and the cytoplasm and in mitochondrial biogenesis.

Summary

Lower organisms make excellent model systems in aging research if they have facile genetics. The premier models of this sort are *C. elegans*, *D. melanogaster*, *P. anserina*, and *S. cerevisiae*. Each of these models has contributed to our understanding of aging in mammalian systems. As true metazoans, the worm and the fruit fly have revealed the operation of a conserved signaling pathway in aging, the insulin/IGF-1 pathway, which operates in mice as well. Yeasts have one component of this pathway in common, and there may be others as well. Yeasts and filamentous fungi have pointed to the retrograde response as a mechanism that compensates for accumulating mitochondrial dysfunction during aging. The nature of experimental models is to simplify studies. By this token, model systems constitute only an approximation of the phenomenon as it occurs in other organisms. Thus, it is essential to examine carefully the results obtained using model systems when attempting an extrapolation. It is certain that some features of the model systems will not have counterparts elsewhere. However, the generalization that there are four fundamental processes that determine life span (metabolism, stress resistance, chromatin-dependent gene regulation, and genome stability), which was developed in studies of yeast, has withstood the test of time. This provides optimism in the utility of model systems in aging research.

See also: Cellular Aging: Growth Factors and Cellular Senescence; Theories of Aging: Biological.

Further Reading

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Models of Aging: Vertebrates

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Glossary

Animal Models – Animals used in experimental settings as surrogates for human subjects.

F_1 Hybrid Strain – Progeny resulting from the mating of animals from two different inbred strains of the same species.

Genotype – The genetic constitution of an individual.

Inbred Strain – A population of individuals within a species with an identical or nearly identical genotype as the result of inbreeding.

Inbreeding Depression – The decrease in vigor including a decreased longevity that normally accompanies a program of extensive inbreeding.

Life Table – A concise, standardized summary of population survival characteristics in relation to age.

Mammals – The class of vertebrate animals that are warm-blooded, possess hair, and suckle their young.

Species – A taxonomic category of living organisms within which effective gene flow occurs or could occur.

Vertebrates – A major subgroup of the phylum Chordata composed of animals possessing an internal bony skeleton, particularly a backbone.

Introduction

Animal models are used in gerontological research for the exploration of aging processes, with the ultimate goal of uncovering the basic nature of human aging. In choosing a particular species or strain of a species as a model, certain criteria should be considered; the extent to which these criteria are met is a significant factor in the success of the study. In executing these studies, it is critical to pay careful attention to animal husbandry issues. Although a variety of vertebrate species have served as animal models for aging research, most studies have used mice and rats. However, the future use of a wide diversity of species is essential since only such diversity can lead to the accumulation of knowledge needed to meet the growing gerontological challenges of this century; the increasing public opposition to the use of animals for biomedical research poses a problem for attaining this knowledge.

Role of Animal Models in Aging Research

Animal models serve as surrogates for humans in biomedical science since they enable studies that cannot be done on humans because of legal, ethical, economic, or technical considerations. The basic premise underlying their use is that much of what is learned will apply to the human condition. The validity of this premise for a particular model is often questioned, and new species continue to be assessed in the quest for a model that most closely mimics humans.

These considerations also apply to the use of animal models for aging research, because human aging is the ultimate interest of most gerontological investigators. However, because of logistics peculiar to aging research, the aim of similarity to humans is often compromised. For example, rodents, rather than non-human primates that are phylogenetically much closer to humans, are the mammalian models most often used; the cost of maintaining rodents and their relatively short life span make aging studies more feasible and much easier to conduct. The likelihood that basic aging processes are similar in all mammalian species is the scientific justification for this choice. Nevertheless, there is growing recognition that valuable information about aging can be most readily gained by studying a spectrum of species, those phylogenetically closer to humans as well as those further removed. A case in point is research on invertebrate animal species, such as the nematode (*Caenorhabditis elegans*) and the fruit fly (*Drosophila melanogaster*). Of course, the interest in exploring aging processes in diverse species relates, in part, to our curiosity about the varied mechanisms of aging that have evolved in living systems. In addition, mechanisms that are well developed and easily studied in a given species may yield insights on aging processes that are expressed in a subtle and less easily studied fashion in humans. Therefore, although this article focuses on vertebrate (primarily mammalian) models, it should be noted that invertebrate animal species, as well as other species such as yeast, can provide, and have provided, important information on aging; this should be kept in mind when choosing a model for the exploration of a particular question.

Criteria for Selection of Animal Models

In addition to relevance to the human condition, there are several other criteria that should always be considered when choosing a model because of their impact on the successful execution and interpretation of any aging study. Of course, no one model is likely to be optimal in regards to all of the criteria. However, the extent to which a species or strain of species meets these criteria should be carefully weighed, along with factors relevant to the specific research question.

Availability of Life Table Data

Life tables contain the mortality characteristics of an animal population. Such information as the median length of life, the age of tenth percentile survivors, etc., is readily obtained from the table. These facts are needed when designing an aging study; without such data, gerontological interpretation of the findings is not possible. For example, an investigator using a specific strain of rat was unaware of the life table data available for that model as he made gerontological interpretations of data from rats ranging in age from 1 month to 6 months. Because the rat strain he chose has a median length of life of about 24 months and the age of the tenth percentile survivors is about 32 months, the interpretations were meaningless. Since life tables are available, the ignorance of the investigator was the problem. However, life tables are not available for many species and strains of species; in such cases, investigators must undertake the time-consuming task of generating a life table for the particular species or strain of species before designing the aging study. For example, some researchers studying atherosclerosis used rabbits as the model, and they interpreted their findings in gerontological terms, despite the fact that there are no reliable life tables for this species. Clearly, the first order of business should have been the generation of a life table for the gender and strain of rabbit to be used.

Longevity Characteristics

The resources required to execute an aging study are, to a great extent, determined by the longevity characteristics of the animal model. Provided that other factors are not compromised, the shorter the model's life, the better; both the cost of animal maintenance and the time commitments of investigators and their technical staff are thus minimized. One reason why laboratory rodents are the most widely used vertebrate model for aging research is their short life spans as compared to most other mammalian species.

Availability of Data on Age-Associated Pathology

The prevalence of many diseases increases with advancing age, and much of this age-associated pathology is characteristic of a particular species or strain of the species. Whether this age-associated pathology is part of the aging process or a different process is the subject of much debate. Regardless of how this debate plays out, it is critical to know the age-associated pathology of the model when designing a study; lack of such information hinders the ability to appropriately design a study. It is also necessary that a pathological assessment be made of the animals used in the research. In cross-sectional studies involving sacrifice of the animals, such analyses can usually be readily accomplished. In longitudinal studies, pathological analyses are possible at the time of spontaneous death or at the end of the study.

Defined Genetic Characteristics

The genetic characteristics of an animal model population should be known and stable. These criteria aim to permit studies by another investigator or at a later time to be executed with an animal model whose genetic characteristics are ideally unchanged, thereby facilitating comparisons with earlier work. While these criteria can be largely met with rats and mice, it is difficult, if not impossible, to do so with many other vertebrate species. Even with rats and mice, the investigator must take special care to meet these criteria. For example, outbred Sprague-Dawley stocks of rats are maintained by randomly mating the members of the stock. However, the mating is often not sufficiently random and, as a result, Sprague-Dawley rats from different suppliers, or from the same supplier at different times, may differ genetically.

Inbred strains of mice or rats are often used in an attempt to achieve uniformity and stability of genetic makeup. Every animal in an inbred strain has the same or nearly the same genotype as every other animal in that inbred population. Thus, insofar as genotype influences phenotype, inbreeding should maximize the phenotypic uniformity of a population. However, the putative advantage of reduced variability comes with a cost because of the phenomenon known as inbreeding depression. On the other hand, populations of F_1 hybrids (crosses between two inbred strains) are as genetically homogeneous as inbred strains, and they do not suffer from inbreeding depression. Moreover, for many phenotypic characteristics, populations of F_1

hybrids exhibit less variability than populations of inbred strains.

It must be noted that there is a significant drawback in the use of either inbred strains or F_1 hybrid strains. That is, what is being studied may be unique to the specific genotype rather than representative of the species as a whole.

Availability and Cost of Animals

It is a challenge to obtain a wide range of ages of any vertebrate animal species that has been carefully maintained, including a complete record of husbandry. The alternative is for investigators to maintain the animals from birth. However, even for short-lived vertebrate species, such maintenance not only requires sizable funding for food, supplies, and caretakers, but also demands the long-term commitment of animal holding facilities. For long-lived species, most investigators simply cannot marshal the necessary resources; such is often the case even for short-lived vertebrate species. In the United States, the National Institute on Aging (NIA) has partially addressed this problem by subsidizing a commercial supplier's maintenance of several commonly used mouse and rat strains. The NIA not only makes available to investigators *ad libitum*-fed animals of a spectrum of ages, but also provides rodents that have been maintained on a life-extending caloric restriction regimen. In addition, the NIA functions as a supplier of banked tissues obtained from a variety of species. The investigator can contact the NIA to find what is currently available, the eligibility criteria for receiving the animals or tissues, and the application procedure. For the investigator who is unable to maintain the animal model of his or her choice from birth or from a young age and either the model is not available from the NIA or the investigator is not eligible for NIA-maintained animals, there are various other possibilities. These include contracting with a commercial supplier or collaborating with another laboratory that is maintaining the model. In such cases, it is vitally important for the investigator to make certain that the husbandry procedures used by the supplier or the collaborator are appropriate and that the lifetime characteristics, such as body weight and dietary history, are available.

Animal Husbandry Issues

It must be recognized that long-term studies, such as those carried out in aging research, are markedly influenced by the conditions under which the animals are maintained. A telling example is a study with female C3H/HeJ mice that are prone to develop mammary tumors. In a conventional holding facility, 65% of these mice developed such tumors by 400 days of age, compared to only 10% of those mice protected from the noise and odors of a conventional facility. Clearly, for most aging studies, it is imperative to maintain the animals in a defined and optimal environment. With effort, this can be achieved when the investigator maintains the animals from birth. However, it is a challenge to be certain that such is the case when animals of various ages are obtained from a commercial supplier or another external source. The following are factors that must be carefully addressed.

Housing

The size and number of animals per cage have long been important considerations. In fact, there are regulations about the cage size relative to the size of the animal and the number per cage. Surprisingly, these regulations do not appear to be based on hard data. For instance, in the case of number of animals per cage, the published data have ranged from greatest longevity for singly housed rodents to just the opposite. Perhaps both a high-density population and isolation entail stress. However, different species and strains of species probably vary in this regard. Thus, the optimal size of cage and number of animals per cage must be determined specifically for each animal model. Moreover, the question addressed by a study may determine the specific housing needed. For example, if the study includes collection of data on the food intake of each animal, then single housing is required. Although there are still many questions concerning optimal cage size and/or number of animals per cage, it is essential that investigators standardize this aspect of the study and that they clearly present this information when publishing the work. Failure to do so makes it impossible for others to repeat the study.

Bacterial, Viral, and Other Infections

Infectious disease can distort an aging study. With mice and rats, this problem can be dealt with relatively easily by utilizing specific pathogen-free animals. Specific pathogen-free means that a predetermined consortium of pathogenic organisms is absent; specific pathogen-free status is evaluated by serologic, culture, and histopathologic analyses. The rodents should be housed in a barrier or related facility that maintains the specific pathogen-free status. Such facilities vary in structure and complexity, but the aim of all is to exclude the entry of pathogens. So-called sentinal animals are maintained in the barrier facility for the sole purpose of monitoring the specific

pathogen-free status; periodically during the course of the research, one or more of these sentinel animals is removed and assessed for specific pathogen-status. The results of this monitoring should be reported when publishing the research findings. Unfortunately, in the case of many mammalian species, maintenance of the animals in a specific pathogen-free state has not been well developed, and this presents a problem for investigators using such animal models.

Diet

Studies with rodents have shown that diet can profoundly influence aging processes. Indeed, it is well established that decreasing dietary energy intake by mice and rats markedly extends the life of these species. Less information has been reported in regard to aging and diet for other vertebrate species, but based on the limited data available, it appears that diet influences the aging of most, if not all, vertebrate species. Thus, diet is a factor that must be defined and controlled; the composition of the diet and the amount consumed should be reported in any publication of such research.

Exercise

The level of physical activity is another factor that is believed to influence aging. However, this factor is difficult to address in animal studies. The investigators can provide animals with the opportunity to exercise (e.g., by providing rodents with running wheels), but the animal and not the investigator determines the extent of physical activity. When publishing an aging study, all information on exercise (including the lack of exercise) should be reported.

Other Environmental Factors

Many other environmental factors have the potential to affect aging studies. Therefore, as far as possible, the environment of the holding facility should be defined, controlled, and reported in publications of the research. The effects of noise and odors have already been mentioned. The intensity of light and the dark–light cycle need to be controlled. Ambient temperature should be maintained in an optimal range for maximal longevity. Adventitious chemicals from bedding materials or disinfectants or insecticides should be avoided; even at low levels, such substances over a long period of time may markedly affect aging studies.

Vertebrate Species That Have Been Used

Fish

Although fish have been used as models in a few aging studies, remarkably little work has been done with this vertebrate class. This is both surprising and unfortunate because the rate of aging varies greatly among fish species, ranging from imperceptible to very rapid. Clearly, fish are a relatively untapped but potentially valuable source of animal models for aging research.

Birds

Birds are another class of vertebrates used only to a limited extent as models for aging research. Because most species of birds are much longer lived than mammalian species of similar size, birds may be uniquely useful models in that they may have specialized protective mechanisms against damaging agents related to the aging processes. Thus, studies with birds may well provide important insights on aging processes and on possible interventions of human aging. Several commercially available bird species seem well suited to serve as models for such research.

Mice

The mammalian species *Mus musculus* (the laboratory mouse) has been widely used as a model for aging research. Indeed, it is the preferred mammalian model for the study of the genetics of aging because of the availability of many genetically defined strains (more than 500 inbred plus many F_1 hybrids) and because of the detailed knowledge of its genome. Moreover, the molecular technology for the generation of a spectrum of genetically altered mice is well developed, ranging from abolishing the expression of a gene to its marked overexpression. The longevity characteristics of many mouse strains have been determined and found to vary significantly among strains. The small size of the mouse has both positive and negative impacts on its use as an animal model for aging research. Its small size reduces the resources needed for maintenance, with the relatively small space requirement a major plus. However, the amount of biological material that can be obtained from a single mouse is quite limited, and physiological measurements on such a small animal are a challenge. Husbandry is well worked out for mice, and there is a wealth of information on age-associated pathology for some strains. The development of manipulations that slow aging in animal models has proven to be a powerful tool for the study of aging. Mice are extremely useful in this regard since the environmental manipulation of caloric restriction slows aging in this species, and genetic alterations (both those occurring spontaneously and those resulting from the use of the tools of molecular genetics) have been found that extend the life of mice.

Rats

The rat is another mammalian species that has been widely used as a model for aging research. There is much information on husbandry and age-associated pathology for several stocks and strains of rats. In addition, life table data are available for several rat stocks and strains. Moreover, the size of the rat is a plus in that it enables physiological and pathophysiological analyses to be readily accomplished. Also, a single rat provides sufficient material for most biochemical and related analyses. Indeed, longitudinal life span studies, involving periodic blood sampling or other physiological measurements, can be accomplished without compromising longevity. As with mice, caloric restriction extends the life of rats.

Hamsters

Hamsters are mammals that have been used only to a limited extent for aging research. The species most used is the Syrian hamster, *Mesocricetus auratus,* but the Chinese hamster, *Cricetulus griseus,* and the Turkish hamster, *Mesocricetus brandti,* have also been used, and life table data are available for all three. Syrian hamsters, including several inbred strains, are available from commercial sources. Although husbandry has not been as thoroughly studied as for rats and mice, the information on hamsters is adequate for the execution of aging research. About the same size as the mouse, the Chinese hamster has the same size-related advantages and disadvantages. Syrian hamsters and Turkish hamsters are much larger than mice, but are less than half the size of rats. Thus, these two species are easier to use for physiological measurements than mice. There is a sizable literature on the age-associated pathology of Syrian hamsters and Chinese hamsters, but not for Turkish hamsters.

Cats

The cat is a mammalian species that has been widely used for research in neuroscience. Since nervous system dysfunction is a major problem encountered in human aging, cats are potentially valuable as an animal model for aging research. However, very little use has been made of them in this regard. One reason is the lack of a readily available source of well-characterized cats. Indeed, the only cat colony with the characteristics needed for aging studies was one maintained by the British Medical Research Council at Mill Hill. However, that cat colony was not used for aging research. The little aging research done with cats has been accomplished by investigators who pieced together a range of ages by obtaining cats from a variety of sources: university-maintained animals, commercial sources, and pets made available by veterinarians with consent of the owners. Clearly, this has not provided investigators with a reliable, well-standardized source of genetically defined animals. On the positive side, life tables and data on age-associated pathology collected on pet cats are available. Of course, cats are large and long-lived compared to rats and mice, which makes aging studies expensive.

Dogs

It has recently been shown that caloric restriction extends the life of dogs, the first non-rodent mammalian species for which this has been demonstrated. While widely used as a mammalian model for physiological studies, the dog has not been a major animal model for gerontological studies for many reasons. A major reason is that well-characterized dogs in a range of ages are not commercially available. In fact, much of the aging research on dogs has involved control groups of dogs in studies on the effects of ionizing radiation. For such research, a breeding program was established to develop a beagle colony with a stable gene pool; clearly, such colonies are needed to provide dogs for aging research. On the positive side, life table data are available for beagles and Labrador retrievers maintained under laboratory conditions. Also, much is known about the husbandry and age-associated pathology of dogs. Of course, dog breeds vary greatly in size, but even the small breeds are large compared to laboratory rodents, making them costly to maintain, particularly in regard to the space required. For example, the beagle weighs about 10 kg (most rats weigh less than 1 kg and mice less than 0.1 kg). Moreover, appropriate care of dogs requires attention to their social environment, including an exercise program, which can be quite costly in terms of time.

Non-human Primates

Because of the long life span of most non-human primate species and the high cost of maintaining these mammals, it is difficult to use them as models in aging research. Nevertheless, there are at least two reasons such models must be used for aging studies. The first is to make certain that gerontological findings in other vertebrates (primarily mice and rats) are also seen in non-human primates; because of their phylogenetic closeness to humans, it is assumed that aging processes in non-human primates are likely to occur in humans. The second is to study those age changes that occur only in humans and non-human primates. In the United States, government-sponsored primate centers generally employ good husbandry and maintain careful records on each animal. Commercial suppliers are also a source of these animals, but in many instances,

the quality of care may be questionable and information about the animals is lacking. In the past, genetic characterization of the primate model has been nonexistent. However, this problem has been rectified by breeding programs in United States government-supported primate centers and in other institutions funded from a variety of sources. Also, genetic characterization of primates has been greatly facilitated by advances in molecular genetics. Although life table data are available for several non-human primate species, the quality of these data is often less than desirable; this has led to the conclusion that currently available information on longevity characteristics must be viewed as tentative. Non-human primate species vary greatly in size; squirrel monkeys, for example, are in the size range of rats, while other species span a range of sizes similar to those seen in various breeds of dogs. Although husbandry is rather well developed for some species of non-human primates, such as the rhesus monkey, much remains to be determined for other non-human primate species, for example, marmosets. It must be emphasized that social environment is a major issue that needs to be addressed when using non-human primate species. Substantial literature is available on the age-associated pathology of several non-human primate species.

Current Issues and Status of Animal Model Use

Since 1970, there has been great progress in the development of rat and mouse models for aging research. In fact, husbandry for these two species is such that their life span maintenance can now be carried out relatively easily.

This has led to the dominance of rats and mice as models in vertebrate aging studies. This dominance is unfortunate because the use of diverse vertebrate models would almost certainly provide new insights of great value in our quest to understand the biology of aging and, in particular, human aging.

Of course, it is important to make certain that the quality of husbandry developed for rats and mice is adhered to when other models are used. Alas, the information needed to meet this standard is not available for most other species. Also, in each case, these data will be costly and time consuming to obtain. For example, reliable life table data for rabbits will require studies of many years' duration. Similarly, determining husbandry requirements for maintenance of a previously unstudied species will require careful study of dietary needs, environmental temperature, and caging requirements, and a host of other factors. In addition, information on age-associated pathology must be developed for each species. The bottom line is that while diversity of vertebrate animals is clearly needed in aging studies, it will require substantial investment. To obtain realistic fiscal support, administrators of funding agencies and members of scientific review panels must be made aware of the whole picture. And the whole picture includes the realization that state-of-the-art molecular biology is of little value in the absence of appropriate animal models.

It is recognized that understanding the basic biological nature of aging will be essential to successfully meet the gerontological challenges of the twenty-first century. It should also be recognized that achieving this understanding requires the use of diverse animal models. Regrettably, in recent years, many laypeople, including a few leaders in the arts and politics, have condemned the use of animal models for biomedical research, and these critics have had a significant negative impact on animal model use.

Probably most of those opposed to the use of animal models are concerned about animal cruelty. Indeed, everyone should have this concern – especially those using animal models for aging research. Nothing is more damaging to the validity of an aging study than the maintenance of the animals in a less-than-optimal environment. As is evident from this article, husbandry procedures must be employed that provide an optimal diet, maintain optimal environmental conditions, and protect the animals from infection by pathogenic organisms. To do otherwise is counterproductive from an experimental standpoint, let alone humanitarian considerations. Of course, physiological measurements need to be made, and they may perturb the animal. However, the extent of the perturbation should be no greater than what humans experience when undergoing tests by physicians. To markedly perturb would be experimentally counterproductive. When sacrifice of an animal is required, it can and must be accomplished without pain.

Many ask why use animal models for aging research when there are alternatives. One suggested alternative is the use of cells in culture obtained from consenting humans. This is not an option since there is no evidence to support the view that cell culture systems serve as models of organismic aging; even scientists who champion their use recognize that cell culture systems serve as adjuncts rather than replacements for animal models. The other suggested alternative is the use of computer models. Given the current state of the gerontological knowledge base, there is no way in which computer models can replace animal models. On the plus side, computer modeling can be a powerful tool for optimizing the use of animal models.

See also: Models of Aging: Invertebrates, Filamentous Fungi, and Yeasts.

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Modernization and Aging

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Glossary

Extended Households – Related or unrelated people sharing the same living quarters.

Independent Living – Non-family and family households who share living quarters in a unit that has a full bathroom and kitchen within the unit.

Neighborhood Families – Formal and informal support structures to households, with easy access to aging households, and replacing some functions that individual families provide.

Introduction

Modernization theory was used to promote a western model of development in the 1950s. By the 1970s, scholars rejected the idea that this theory was a blueprint for industrialization and democracy in developing countries. The idea that progression was linear was discredited. In the 1970s, the research agenda for aging expanded to include issues about the older population in developing nations. Researchers on aging agreed that a demographic revolution was occurring based on the worldwide growth of the older population in the twentieth and twenty-first century. The demographic revolution affects and is affected by modernization. Revised modernization theory offers insight into the implications of an increasingly aging population in developed and developing countries undergoing globalization. This article begins with an overview of the demographics of aging and then reviews alternative views about modernization in relation to globalization. A description of the demographic revolution's influence on household and family structures, living arrangements, and the intersection with modernization follows. Aging issues in community, housing, labor, and employment policies are explored. The last section turns to a description of global institutional policies and proposed transnational policies. Under globalization and given governments' weak commitment

and/or budgetary problems, the role of civil society as being significant in enfranchising older populations is discussed.

The Demographics of Aging

The United Nations Department of Economic and Social Affairs (UN DESA) has stated that population aging is unprecedented, pervasive, and enduring and has profound implications. The reasons for increased aging are due to numerous interrelated factors.

- Mortality and fertility rates are declining, increasing the proportion of the older population. Grandparents will outnumber children.
- Longevity is increasing. In 2002, it was 66 years. In the least developed countries, men who reach 60 can expect to live another 15 years and women 16. In developed regions, life expectancy at age 60 is 18 years for men and 23 for women.
- The fastest growing population in the world is 80 and over. About 180,000 persons worldwide are centenarians and their numbers will reach 3.2 million by 2050.
- The majority of older persons are women. The percentage rises among the oldest. In developing countries, among people over 60, the ratio of men to women is 88 to 100; in comparison the ratio is 71 men for every 100 women in developed countries.

Absolute numbers are dramatic. The numbers of those 60 years and over will reach about 1.2 billion by 2025 and 2 billion by 2050. The overall rate of growth for older persons is increasing faster than the population as a whole. In 1950, the proportion of older persons was 8%; in 2000 it was 10%; by 2050, it is projected to reach 21%. The most startling revelation to many is that population aging is occurring faster in developing countries than industrialized. According to the World Health Organization (2002), "In 2002, almost 400 million people aged 60 and over lived in the developing world. By 2025, this will have increased to approximately 840 million representing 70 percent of all older people worldwide." The growth of the older population is changing the profile in communities and preferences for living arrangements. Migrating working adults are leaving more elderly behind in rural areas in developing nations, and the elderly in urbanized areas in developed nations are facing a lack of affordable housing.

- About one-third of the world's older population lives in rural areas, but 51% live in urban areas. The percentage of older people in urban areas in developed nations is 74% compared to less developed regions, where only 37% live in urban areas.
- Three-quarters of population growth will occur in second-tier cities and smaller urban areas with populations between 100 000 and 500 000.
- The growth of the older population bears directly on labor, employment, and immigration policies.
- From 1950 to 2000, the ratio of working-age adults (15 to 64 years of age) per person 65 years and over – the old age dependency ratio – dropped from 12 to 9 and is expected to fall further to 4.

Too often overlooked in the attempt to fully appreciate the relationship between modernization and aging are distinctions among the older population. In addition to differences among and within nations, regions, development status, and rural or urban location, the older population varies by class, race, ethnicity, education, gender, sexual preference, marital status, religion, culture, etc.

Statistics tell one side of the story. Considering the implications of modernization makes aging seem far more complex. Analysis cannot simply target a specific age as old or elderly. For example, in France, most men retire between 55 and 64 years of age, but pressing demands to offset the decrease in the labor force of younger working-age adults may reverse the trend of early retirement. Age targets overlook the variations among the old as a result of longevity and medical advances in treating infectious diseases in many regions of the world. The 'new old aged' or active aged engage in sports, education, sexual activity, and work at ages once thought to be devoted to extremes of idle leisure or isolation. Demographic shifts can shape the ways in which neighborhoods are experienced, that is, as senior ghettos or as age integrated. This also depends on how policy makers distribute resources to satisfy the needs of an area in which the elderly are a majority.

The life course concept is a way of integrating modernization and globalization trends. The life course identifies interacting policies or nests of policies that have effects throughout one's life. Old age is no longer a fixed status but is subject to circumstances that can shift back and forth in response to numerous environmental factors, including education, urbanization, medical advances, residential segregation, and migration. The life course takes into account the fact that policies that influence people in their earlier years will also have repercussions in later life. For example, a mandatory education policy for young girls will affect later choices about pregnancy, the number of children conceived, and whether women have greater options in the labor

force. As mortality rates and fertility rates decline, a result of advanced technology and health and education policies, community and family institutions are altered. Tied to these policies is the need to rethink the belief that modernization leads to less respect for the elderly.

First, what is meant by modernization and the relationship to globalization?

Modernization and Globalization

The term modernization can be explained in multiple ways. The framework includes the shift from agriculture to industrialization, institutionalizing democratic government, creating bureaucracies, the spread of urbanization, and the increasing use of technology. Modernization is sometimes used interchangeably with globalization. Other times, globalization is referred to as a near cousin to modernization, that is, the economic and social underpinnings that lead to development. Globalization is also used as an umbrella term for modern, postmodern, or late modern periods when national priorities rapidly change, the social order becomes more diverse, and the elderly are less likely to be placed in institutions.

One question is whether or not modernization aptly describes societies in which industrialization is subordinate to the informational economy. The expansion of financial integration into a global market and the growth of the health-care, education, and transportation sectors depend on a stable, reliable, and fast informational economy. Douglas Kellner, in the essay "Globalization and the Postmodern Turn," identified a current period of transition where "globalization signifies both continuities with the past, with modernity and modernization, as well as novelties of the present and the already here future."

Modernization theory varies over time. The first wave of modernization theory appeared in the social sciences in the 1950s and 1960s, although the concept reaches back to seventeenth-century European thought. The second wave of critical theory in the 1970s and 1980s was an attack on the imposition of western ideas on developing countries. In the 1990s, a postmodern interpretation was linked to a third wave of globalization.

Modernization theory emerged after World War II, a time when the United States was considered a superpower, European nations withdrew from or were forced to leave their colonies, and a power center coalesced around the Soviet Union and communist ideology. The Cold War divided the globe into friends and enemies of the United States. Tension existed between communism and democracy. Scholars such as Walter Rostow postulated that the United States was the model to be emulated and that foreign aid should be used to kick-start progress in developing nations as they passed through the evolutionary stages from craft to mass production. The promised result would be economic growth leading to higher per capita income. Social benefits would include raising the standard of living. The combination of economic and social improvements would result in favorable conditions for institutionalizing democracy.

In the second wave of modernization theory, critical theorists reacted strongly against the model's western bias, failed policies, persistence of poverty, and the rise of dictatorships. The Cold War mentality blinded policy makers to differences among countries and nation-state identity that wars did not eliminate. In the late 1970s, privatization policies escalated. In some countries, nationalization of utilities, transportation, and state-run housing bureaucracies was criticized as being inefficient and unprofitable. New Zealand and Great Britain led the way in selling their nation's assets to the highest bidders. Except for China, Cuba, and Vietnam, primarily in Asia, Africa, and Latin America, nationalization within a country wrested economic control from a market-dominated minority.

The current wave of postmodernization theory acknowledges an increasingly complex and uncertain world where financial integration is accompanied by social fragmentation at the individual and societal level. Modernization may occur in some parts of a country or region and not in another. According to Michael Hardt and Antonio Negri, economic miracles in one sphere, as in Italy's knowledge industry, can co-exist with less complete transformation in another sphere, such as small peasant farms. Cheap telecommunications create a global marketplace in which the opportunity to become a producer is just a computer keyboard away, available to individuals, businesses, and the nation-state.

In this hyper-marketplace, generous social welfare programs in many industrialized countries are dumped. Dwayne Swank refers to diminished democracy, in which democratic institutions are unable to sustain policies when market measures are used to determine success. Former state socialist countries are adopting legal tenure systems based on western models of private property rights, escalating the trend toward privatism.

In countries where little social security exists for the elderly, *de facto* policies rely on the family, but the results are mixed as to whether modernization/globalization undermines this traditional support and diminishes the worth of the older population. In Kenya, the once special status of elders has given

way to viewing elderly slum dwellers as unsuccessful because they do not have money to return to their home villages and grow old. In India, the authority and prestige of old people is being replaced by the idea that they are a burden. Distinctions between younger and older elderly can change the dynamic. For example, according to one study, younger elderly married people who live in rural areas in the Republic of South Korea, who have more modern attitudes, and whose children are educated have more power than older elderly. A similar finding was observed in the Philippines.

Modernization/globalization is multifaceted and can lead to positive outcomes, but the outcomes can generate unintended consequences or insufficient change. Physical longevity may occur as a result of wiping out infectious diseases, yielding higher crops, and improving nutrition and sanitation. However, income may still be too low for the elderly to afford housing and other necessities. Literacy may increase, but limited access to advanced technology during younger years may not lead to higher-skilled well-paying jobs that provide economic security in old age. Globally, individuals with disabilities are expected to decline in number, but survivors may be unable to afford 'assistive technology' that helps increase their functionality. Wars, skirmishes, and ethnic clashes restructure land holdings, but they do not eliminate unequal distribution of power among men and women and can result in older people losing their claims to property and relative security.

Some scholars suggest that modernization theories and by extension globalization theories are helpful on a macro- but not a micro-level scale. Kellner says that globalization is most apparent in the 'realm of culture' in terms of consumer products, images, and ideas, and questions whether the homogenization of global culture is so overpowering as to sever ties to local places, break religious and ethnic identities, and replace the role of nation-states. While some scholars support globalization, deregulation, the openness of trade borders, and international financial integration, Chua lists negative consequences to these events such as ethnic conflict, militant Islam, taking property, killings, displacement, and genocides. In short, globalization, like modernization, should not be misunderstood as progress. Such events are devastating to the cultural and collective memories of the older population.

In developing nations, even among the 'Asian tiger' nations who sustained financial success and 'won' transnational corporations and foreign investment to their shores, poverty is pervasive. The United Nations HABITAT reports that in 2001, 924 million people were slum dwellers – 31.6% of the world's urban population, 43% in developing regions, and 6% in developed regions. The number of slum dwellers might increase to as high as 3 billion by 2050, absent any interventions. The litany of slum conditions – lack of basic services, unsafe buildings, overcrowding, and lack of tenure – is a declaration of non-modernization in a globalizing world. The aging population suffers along with other slum dwellers, compounded by lifelong difficulties with nutrition, health, and multiple pregnancies among women.

The lack of public accountability under modernization/globalization is writ large in Africa, where the 'modern' disease HIV/AIDS has systematically broken up families. The African continent has a young population, but the number of elderly aged 77 to 84 is expected to grow, and it is questionable whether the government and community can offer support. Currently, elderly women are the primary caregivers for children and ill relatives, but this care infrastructure is fragile given that older women are also susceptible to HIV/AIDS.

Gender reform is closely linked to modernization. The role of women in developed and developing nations is tied to their class and society's cultural and religious values, norms, and laws, which shape family and household structure.

Family, Household Structure, and Gender

Family and household structure and the diversity of social arrangements are a function of demographics, but demographic changes interact with urbanization, industrialization, and the influence of religion.

In industrialized countries, the dominant model of the nuclear family is a working husband and stay-at-home wife. Lifestyle choices, rising divorce rates, formation of single parent households, same-sex couples living together and/or marrying, and the elderly choosing to live independently have all contributed to various types of household structures. The diversity in industrialized countries is linked to women experiencing greater rights, having access to birth control, and benefiting from labor-saving devices in the home, all of which enable them to participate more fully in the labor force. This is constrained by the scarcity of child-care programs, particularly for single parents and women of color who rely on older caregivers among their family, friends, and kin. Conversely, Hardt and Negri suggest that in countries where Islamic fundamentalism is practiced, the belief in a traditional family can be interpreted as postmodern. A rejection of western models of diverse family institutions and liberatory policies for women is consistent with thinking that western life is generally corrupt.

Women in developing nations have fewer rights than women in industrialized countries. Although women produce between 60 and 80% of the food and are the foundation of small-scale agriculture, their status declines as they get older, and their conditions worsen with less access to resources. Because women live longer than men, their widowhood is fraught with financial problems once husbands and sons die. Women are not allowed to own land or apply for credit. Women in sub-Saharan Africa and the Near East are primarily responsible for animal husbandry, processing, and marketing. Traditions prevent them from starting their own businesses. A lifetime of earning low incomes and the absence of savings increase older women's dependency as they age. Wage discrimination for women in industrialized nations leads to similar consequences, although their rights are greater.

Bongaarts and Zimmer's research on living arrangements in 43 developing countries showed that elderly women were nearly twice as likely to live alone as men. Asian elderly are more likely to be living with children compared to Africans or Latin Americans. A preference for living with adult male children is evident in Asia, but gender preferences are not homogeneous even there. Education levels, rather than wealth and urbanization, are more likely to influence the elderly's living arrangements. The higher the level of education, the greater the likelihood that the household is smaller, and the greater the chances for living alone.

Ultimately, the choice of living arrangements may be constrained by housing options. The interaction of changing compositions of living arrangements and increased urbanization in market economies has led to housing crises all over the world.

Community and Housing

Issues about community and housing are directly related to not only increased urbanization, but also migration of working-age adults and government policies. Housing policies have community-wide impacts; the housing package includes the community setting. Older people are best served when public transportation, commercial facilities such as markets and pharmacies, and recreation and community health centers are within walking distance. Public social venues where the elderly can meet can offset feelings of isolation and contribute to preventive health practices. Canada is exploring ideas of combining recreation centers and schools with wellness centers where the elderly can conveniently find health services. Safety in communities is an important issue that has been taken up by women's groups in collaboration with municipalities. Increasing the number of bus stops and instructing drivers to stop closer to destination points help enable the elderly to have access to greater mobility.

In industrialized countries, the degree to which a country supports the older population depends on factors such as tax incentives, community-based programs, and financing for innovations such as 'smart houses' that incorporate technological advances. In the United States, homeowners receive government tax relief, the deepest subsidy program in the form of tax write-offs that totaled about 73 billion dollars in 2005. Public housing, which encompasses only 1.4 million units and which is routinely underfunded, houses one-third of the elderly, with the largest subsidy program for poor seniors of color. Whether single-family owner-occupied homes or public rental housing, these units may not be modernized and may lack supports for aging. Conditions become worse for the elderly under inflationary periods, when expenses for food and utilities can rise. In other cases, the government's withdrawal of subsidies, as with Russia in 2004, deprives the elderly of essential benefits.

At the same time that modernization/globalization promotes independence, the private housing market, particularly in large metropolitan areas, is too expensive for older people on fixed incomes. The International Alliance of Inhabitants documents worldwide forced evictions in developing and developed nations in cities such as Nairobi, Kenya and Rome, Italy. Displacement can be government driven. In countries that once had deeper social housing programs, for example, England, government selling of council housing accelerated gentrification in areas ripe for market development, with the effect of displacing poorer people who could not afford the rising rents.

In Singapore, where the government plays a substantial positive role, 81% of the people live in public housing. In Hong Kong, 47% of the population lives in public housing. In countries where Confucian values promote reverence of the elderly, cultural values may concede to pragmatic decisions given urbanization. Co-residency in China, Taiwan, Singapore, and Hong Kong is sensible considering their conditions of a shortage of affordable housing. The possibility of co-residency must be weighed against the option of living in urban areas in smaller apartments and cramped quarters. Policies to counter adverse modernization trends can help keep families intact. Housing-related policies promote co-residency, such as in Hong Kong, where families with elderly persons are given priority for obtaining housing. Singapore favors young people who live in multigenerational households.

Housing policies reinforce and reflect racial and ethnic as well as economic segregation. Spatial patterns become 'fixed' for life, especially because the generally agreed-upon consensus in industrialized nations is that older people should age in place. The availability of housing options impacts the lives of older as well as younger populations regarding whether communities are mixed by age. In developed countries, age-specialized housing such as retirement homes or continuing care facilities, seniors-only complexes, and group homes is increasing. Shared living services match people in assisted housing, where collective spaces can include kitchens and living rooms. Direct services such as meals may be provided. Accessory units, sometimes called mother-in-law or granny houses, can be attached to or detached from single family houses; the arrangement can be with kin or not. Japan offers something similar in the form of garden suites built adjacent to main houses to accommodate modified extended families.

The elderly who age in place are both renters and owners. In countries such as the United States where health care and nursing homes are costly, owning offers one form of security in old age, although poor elderly homeowners, primarily women, can have trouble paying for other necessities. A primary concern is whether health and other services are accessible and available. In Sweden, for example, a house care and repair program helps the poor and disabled. In Denmark, assistance with shopping and laundry is provided, and elderly residents receive night and evening home-care visits. Increasing numbers of states in the United States are using a combination of federal, state, and local subsidies to provide funding for home-care providers – also referred to as home aides – including paying family members who perform this service. This enables the elderly who meet financial requirements to continue to live independently from families and eliminates the need to place them in nursing homes. As often as not, older women earning low wages are caring for other low-income elderly women.

The most vulnerable elderly include the frail, disabled, and poor as well as those who live in rural areas and urban slums. The United Nations' call for poverty reduction programs is based on increasing ways to earn a living and providing greater access to credit, especially for women. Other approaches are through labor employment policies. John Myles reports that Canada and Sweden have less than a 5% poverty rate in the older age group; the former offers a guaranteed annual income to the elderly, and Sweden offers a guaranteed minimum pension.

Labor and Employment

Labor and employment policies under modernization/globalization influence and are influenced by the role that governments play in achieving economic stability for the individual and the society. In industrialized countries, income for the elderly includes pension plans, savings, private investments including stocks and real estate, and long-term care insurance. The elderly may continue to work, reduce their hours, or find new part-time jobs. These options are insufficient for those whose earnings were limited at younger ages or who held jobs that paid moderate wages and either had no pensions or had pensions with limited benefits. Women in particular face an uncertain future given past discrimination.

The role that governments play in providing social security for the elderly in industrialized nations is in transition and is linked to changes in the market, the decreasing ratio of working-age adults to elderly, and lower fertility rates. This affects policies regarding education and immigration. Education and job training can be promoted as a way to retrain older people. Another alternative for replacing the growing older work force is recruiting additional women into the labor force, although individuals have been entering for reasons of survival as well as raising their standard of living. Flexible policies about immigration are a contentious issue in many industrialized countries where questions are being raised about citizenship and rights to housing, among other benefits. Immigration, particularly when not legal, is a factor in debates about who is responsible for retirement benefits.

Retirement programs are an aspect of employment policy. Choices about extending the retirement age, reducing social security payments, and increasing the hours in the work week are designed to combat disruptions that the private and public sector encounter in the face of rapid globalization. Encouraging the elderly to work longer may be necessary on an individual level, for example, when corporations mismanage pension plans, declare bankruptcy, or lower their contributions. In the United States, there is vehement debate about privatizing social security and switching from defined benefits to defined contribution pension plans in order to reduce government payouts. Unions in industrialized nations have a stake in the debates; they are concerned about protecting the rights of workers as well as hard-won gains such as hours in the work week, vacation time, and health benefits.

In contrast to the elderly in developed nations, it is assumed that the elderly in developing nations will remain economically active throughout their lives.

This is largely due to minimal social insurance programs. There are other difficulties that relate to the degree of modernization. In 2005, Global Action on Aging reported that Nigerian pensioners were dying because they had not received their monthly pensions. The contradictions of modernization/globalization are visible in Ciudad Juarez, Mexico, where medical and nutritional improvements leading to longevity will see the older population doubling between 2000 and 2005, a trend that will continue every 5 years. Meanwhile, the government, civic organizations, and religious organizations are not responding to deaths from illnesses such as diabetes, hypertension, and heart attacks. In East Asia, one scholar warns, countries could go bankrupt trying to take care of the elderly, and the elderly have to find ways to give back to society.

World Organizations and Civil Society

In the face of modernization/globalization, global institutions are proposing policies that are transnational, promoting programs that will optimize the lives of the older population. The United Nations has played a role since 1948, when their activities concerning aging began. In 1982, the World Assembly on Aging adopted the International Plan of Action on Aging, making recommendations about health and nutrition, protection of elderly consumers, housing and environment, family, social welfare, income security and employment, and education. In 1991, the UN adopted principles in five categories – independence, participation, care, self-fulfillment, and dignity. In 1999, the International Year of Older People was observed; in 2002, in Madrid, at the second World Assembly on Aging, the adopted recommendations were comprehensive, including the topics of financial security, health care, housing, and protection against exploitation. The needs of elderly women were included as a priority. The World Health Organization's program for active aging has also attracted global support. Transnational institutions recognize that programs are dependent on resources and urge governments to accept responsibility for developing programs.

In industrialized countries, civil society is playing a major role in advocating for the older population. Volunteer groups have grown from a scattering in the 1950s to become institutionalized organizations after the 1970s. Many types of organizations exist that differ in purpose, numbers, activity, and militancy. Organizations in industrialized countries foster intergenerational relationships, gay and gray lesbians fighting against isolation and loneliness, retirees organized around companies and occupations, professional and business people, and state employees. Among more militant groups in the United States are the Raging Grannies and the Gray Panthers, both of whom have local chapters, some of which are more active than others. Among the most influential groups in the United States is the AARP, a strong lobbying group with a large membership base.

The World Health Organization observes that richer nations were able to get richer before they got older. The developing world will be getting older long before they achieve an infrastructure of support for the elderly. The Organization for Economic Co-operation and Development reports that it took 140 years for the aged population in France to double; in comparison, in China it will take about 34 years and in Venezuela, about 22. Under these circumstances, coalitions of non-governmental organizations (NGOs) are essential as lobbyists, program operators, and capacity builders of organizations. The NGOs may be able to act as a countervailing force in the face of rapid changes. Collectively, the message from NGOs is to demand and promote the integration of the elderly into the development process. The elderly can transmit traditional skills but also can be useful in production industries or in public welfare and safety tasks. In Ciudad Juarez, Mexico, for example, people 60 and over are being hired as members of an unarmed elder police force at elementary schools and parks. In India, more than 500 NGOs are providing services such as old age homes and senior day care centers and are advocating for benefits such as priorities for transportation and hospital appointments.

Civil society and organizations of the older population are essential under modernization/globalization, especially when public responsibility flags and the private sector retrenches. The longevity of the population, the very fact that more people at older ages will remain active, combined with networking power through the technology of the Internet, is significant. The aging population itself can use the tools of modernization/globalization to make visible their needs and rights. The dramatic reversal of the demographic revolution, the rapidity of changes in the market, and a misrepresented faith about the all-encompassing benefits of modernization and globalization mean that the aging population cannot advocate on its own behalf alone. With globalization, it is important to recognize the diversity and differences among young-old and old-old, but at the same time to join with broad-based social movements including the pre-old to challenge the negative aspects of modernization.

See also: Caregiving and Caring; Cultural and Ethnic Influences on Aging; Death and Dying; Diet and Nutrition; Economics: Society; Education and Aging; Ethics and Euthanasia; Frail Elderly; Gender Roles; Globalization and Aging; Images of Aging; Life Course; Organizations On Aging; Politics of Aging; Retirement; Social Networks, Support, and Integration; Social Security; Volunteer Activity by Older Adults; Widowhood and Widowerhood; Wisdom; Work and Employment: Individual; Work and Employment: Society.

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Motor Control

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Glossary

Closed-Loop Control – When sensory feedback is used in the planning, execution, and modification of actions.

Coordination – The simultaneous, smooth motion of multiple body segments.

Kinematics – Descriptors of motion, without taking into account the forces that produce the action (for example, limb displacement, velocity, and acceleration).

Motor Control – The integrative action of the nervous system in the control of posture and movement.

Motor Unit – A group of muscle fibers and the motor neuron that innervates them.

Neural Noise – Random neural background activity arising in the sense organs, neural pathways, and the brain.

Open-Loop Control – When an action plan is generated prior to movement onset; movements are then executed without regard to sensory feedback.

Signal-to-Noise Ratio (SNR) – The ratio between the amount of modulation due to the invariant program component (signal) and the amount of unpredictable modulation (noise). A high SNR suggests a more reproducible movement.

Speed–Accuracy Trade-off – The well-known phenomenon that when a performer attempts to move more quickly, he or she becomes less accurate.

Introduction

Older adults often exhibit impairments in motor performance that can affect their everyday activities. Motor skills are influenced by deficits in processes that occur before a movement, such as slowing in central processing speed, and by changes taking place during performance of a movement, such as an inability to properly regulate force. The speed, variability, and kinematic profiles of older adults' motor responses usually are not comparable to those of younger adults. Some of these declines can be partially mitigated with practice. The causes of these motor performance declines are not well understood. Regardless of the etiology of these declines, they can have a substantial effect on the independence of older adults.

Typically, as individuals get older they experience substantial declines in sensorimotor processing. Motor performance often becomes slower and more variable. Research has also revealed that the elderly show (1) an increase in movement duration, (2) more variable actions, and (3) difficulties with motor coordination. Age-related changes in sensorimotor processing may lead to impairments in motor activities of daily living (ADLs); however, some deficits may be reduced with practice and/or familiarization. The purpose of this article is to describe how aging alters the ability to control and execute movement, and to document the manner in which such movements differ from those of younger subjects. As the topics are reviewed, we present several of the current theories of why such impairments occur.

General Slowing of Movements with Age

One of the more pervasive changes in motor performance with age is an increase in movement duration as seen on a variety of tasks. Older adults are slower to initiate movements in response to stimuli; they also execute movements more slowly than younger adults.

Motor Slowing

The measure of movement time provides information regarding declines in sensorimotor processing. Compared to younger subjects, the elderly execute movements approximately 15–30% more slowly. In addition, they are disproportionately affected by increasing movement difficulty. An example of the effect of increasing difficulty is shown in **Figure 1**. In 1954, Fitts' law was formulated to establish the relationship between movement time and index of difficulty (ID) for aiming movements of varying amplitudes and target widths. This law can be

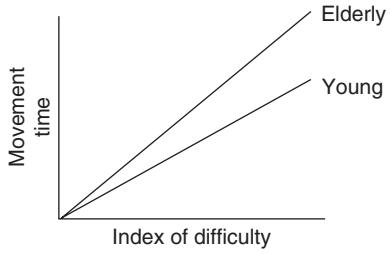

Figure 1 Fitts's law: Movement duration increases as a function of the index of difficulty for the young and the elderly. The elderly show prolonged movement durations with increments in task difficulty.

mathematically represented as

$$\mathrm{ID} = \log_2 2A/W \text{ bits/response},$$

where W is target width and A is movement amplitude (distance from the starting position to the target center). Fitts demonstrated a linear relationship between the time taken to execute a movement and the logarithm of the required relative accuracy. Relative accuracy is measured as twice the movement amplitude, $2A$, divided by the target width, W. Movements of greater amplitudes to smaller targets take longer. To further investigate this phenomenon, performance speed for the young and elderly was compared on tapping tasks requiring movements of three amplitudes to three target widths. The slope of the line relating movement time to index of difficulty increases with age, but not the y intercept. As seen in **Figure 1**, the slowing is not in constant increments, but in increasing increments with age, implying that the elderly take considerably longer to execute movements that require greater precision but have little difficulty with low ID movements. It is important to distinguish whether this effect represents a difference in movement strategies that might be eliminated by appropriate payoffs and/or training, or whether the prolonged movement represents a fundamental limitation of the motor control system present in older adults.

Contributions to Motor Slowing

Explanations of slowing in older adults can be divided into at least three main categories: (1) older adults produce slower movements in an attempt to minimize error, (2) with advancing age, there is an increase in perceptual noise in the system, and (3) with advanced age, there is an increase in motor noise in the system. These explanations are not mutually exclusive and probably overlap to some degree, explaining why older adults make slower movements than younger adults.

Minimizing Error In all movement tasks, an individual must deal with the issue of speed versus accuracy. As the resulting speed of a movement increases, so does the probability of making an error, as these faster movements do not always end at intended target locations. For each task situation, a decision must be made on how to optimize performance with respect to speed and accuracy. Speed–accuracy relationships hold for all age groups, but older adults tend to choose to emphasize higher accuracy levels at the cost of movement speed.

Increased Perceptual Noise Older adults are known to have relatively more noise in their visual processing system than young adults. Such increases in noise are thought to hinder visually guided feedback capabilities of movement-related information. In motor task situations in which some visual guidance is expected, as in the deceleration (or homing in) phase of movement, there would be increased errors from imprecise monitoring and ensuing corrective movements. This explanation postulates that older adults produce slow movements because of prolonged deceleration phases, a well-documented phenomenon associated with movements in the elderly (*see* Vision).

Increased Motor Noise Movement slowing has also been explained by decreases in signal-to-noise ratios. This explanation of slowing is based on the assumption that motor noise increases with the amplitude of force generated. When older adults produce a certain force level, the noise associated with it is thought to be greater than that observed in younger subjects. Thus, this argument suggests that older adults produce slower movements than younger subjects because moving more slowly offsets the changes in signal-to-noise ratio and allows older adults to achieve the same level of accuracy as young adults.

The problem with these explanations is that they are not mutually exclusive. As is apparent, these hypotheses are interrelated and make very similar predictions about motor performance. This explains why it has been so difficult to localize the exact cause of movement slowing in older adults.

Kinematic Changes with Age

Kinematics refers to the branch of mechanics that studies motion without taking into account the forces that produce an action. Movement descriptors such as limb displacement, velocity, and acceleration can be calculated from data captured with high-speed cameras or other motion-monitoring devices. Kinematic investigations have contributed greatly to our understanding of age-related changes in motor control.

Movement Substructure

The kinematics of aiming movements can be divided into two components: an acceleration phase, from movement initiation to peak velocity, and a deceleration phase, from peak velocity to the end of the movement (**Figure 2**). The deceleration phase is seen as a 'homing in' on the target. Kinematic investigations have typically required subjects to perform aiming movements such as pointing at a target or using elbow flexion and extension movements to control a manipulandum that positions a cursor at different target locations. The most readily observable difference between young and older adults is seen in the velocity curve (**Figure 2**). Although young subjects perform movements with symmetrical, bell-shaped profiles, older adults spend a greater proportion of the movement in the deceleration phase (period following the first vertical line in **Figure 2**). This effect is intensified as the accuracy requirements of a movement increase, consistent with a speed–accuracy trade-off strategy for the elderly. This lengthening of the deceleration phase contributes to increases in total movement duration. Although the acceleration phase of movements is assumed to be under open-loop control, with no need for feedback information, the deceleration phase is assumed to be at least partly under closed-loop control, in which error detection and correction information from motor and sensory systems are used. Because the deceleration phase of movement is lengthened with little changes appearing in the acceleration phase, this deficit may depend on the ability of the elderly to efficiently coordinate sensory and motor information.

In aiming tasks, young subjects perform the major portion of the movement as an initial, ballistic primary subcomponent and then employ a shorter, corrective secondary subcomponent (the period after the second vertical line in **Figure 2**) to reach the target. These successive episodes of acceleration and deceleration of the limb are referred to as submovements. Researchers have shown that older adults do not project the limb as far during the primary ballistic submovement and are therefore required to use a longer secondary submovement to reach the target accurately. It is not known why young and elderly subjects exhibit different time profiles for these components. The lengthening of the secondary component may reflect an inability to produce adequate force to rapidly move the limb during the primary component. It may also be caused by the greater amount of time required for older adults to process sensory information regarding position of the arm with respect to the target.

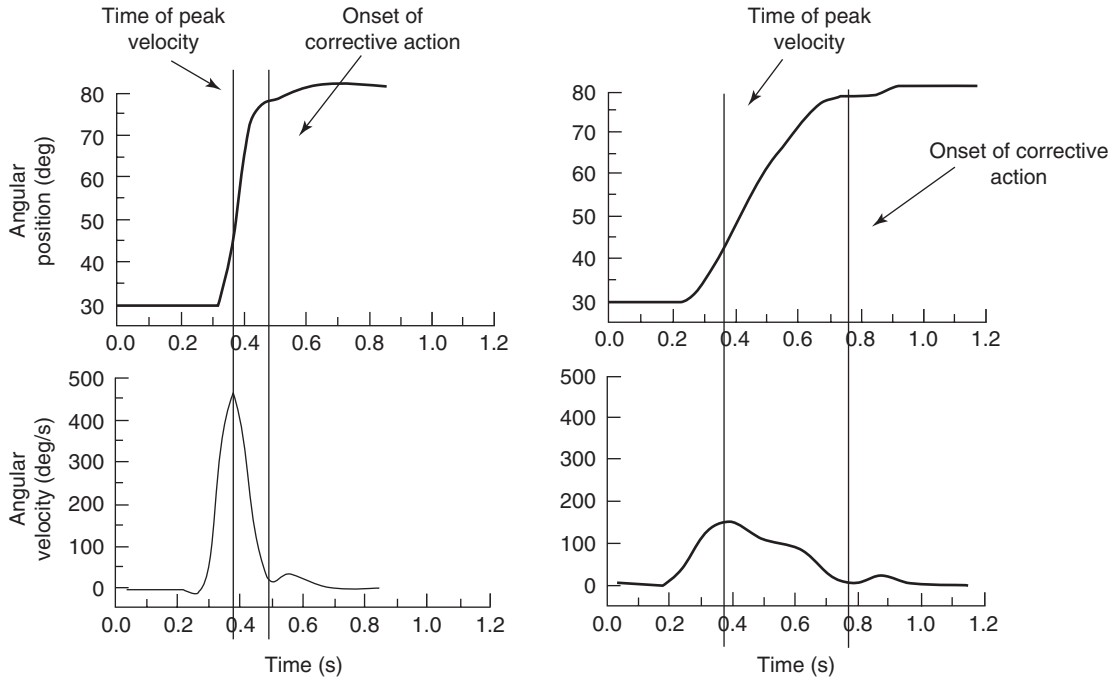

Figure 2 Kinematics of a rapid, aimed movement. Typical results for younger subjects are shown on the left, while those for the elderly are on the right. The acceleration and deceleration phases of the movements are divided by the first vertical line (time of peak velocity). The primary and secondary submovements are divided by the second vertical line (onset of corrective action). The elderly exhibit both a prolonged deceleration phase and an extended secondary submovement in comparison to young adults.

Movement Scaling

When younger adults perform movements of differing amplitudes, the temporal features of the movement often remain invariant; thus, relative timing is preserved. It is normal for the motor system to increase acceleration for movements that have longer amplitudes. As a result, the ratio of peak velocity to mean velocity remains fairly constant when movement amplitude increases. This suggests that the movement pattern remains invariant and is simply rescaled as the amplitude of movement changes. However, this does not appear to occur with the elderly. In a study requiring young and older subjects to perform elbow flexion and extension of varying amplitudes, older adults exhibited greater variation in the ratio of peak velocity to mean velocity, with the highest ratio values displayed for smaller amplitudes. This ratio is more variable for the elderly subjects, suggesting that the amplitude of their movements cannot be modified by a simple rescaling of the initial impulses in order to produce movements of differing sizes.

Movement Variability

Compared to younger subjects, the elderly exhibit greater variability in their movements, with performance fluctuations occurring both between and within trials. For simple elbow movements, the elderly exhibit greater variability for short movement amplitudes in which the deceleration phase of the movement contains several submovements. High variability in this phase suggests that older adults need to make extensive modifications during this final movement.

Movement variability may also arise from peripheral changes in the neuromuscular system. Aging is associated with the progressive death of alpha motor neurons. Some of the muscle fibers that were once innervated by these motor neurons are re-innervated into remaining motor units. These reorganized motor units produce greater force due to their larger number of muscle fibers, potentially leaving older adults with a reduced degree of control over force production, particularly at lower force levels.

Aging is also associated with greater fluctuations in motor unit discharge rates. Computer simulations linking motor unit structure with discharge rates and force output suggest that discharge rates may have more of an impact on muscle force variability than the motor unit reorganization described previously. It appears that older adults can compensate for heightened muscle force variability by co-activating the antagonistic muscles surrounding a joint. However, this compensatory strategy is only employed for simple, single joint actions (*see* Neuromuscular System).

Another factor that can influence trial-to-trial movement variability is the motor control strategy that subjects employ. Older adults make larger errors when vision is unexpectedly occluded during a movement, suggesting that they rely more on visual feedback control for motor performance than young adults. This greater reliance on feedback control is associated with numerous corrections to ongoing movements, producing trajectory fluctuations. When movements are performed in a feedforward fashion, in contrast, a consistent movement plan can be executed repeatedly with little variability from trial to trial. Motor variability decreases with practice for young adults, as movement control shifts from feedback to feedforward. Older adults have shown similar practice benefits in an arm aiming task, with movements becoming more consistent over repeated trials. However, the underlying strategies producing this reduced variability differ between young and older adults. Following practice, younger adults perform a greater portion of aiming movements under feedforward, programmed control. That is, their primary submovement covers most of the distance between the start and the target location. In contrast, elderly adults increase the efficiency with which they use feedback information as a function of practice. After practice, their primary ballistic submovement does not increase in amplitude; rather, their corrective actions become more accurate and make up less of the overall movement. This increased reliance on feedback mechanisms for older adults is associated with slower and more variable movements.

Motor Coordination

Coordination refers to the simultaneous, harmonious action of multiple body segments, resulting in a smooth movement. The execution of coordinated movements requires the precise temporal integration of sensory and motor information. This process begins to break down with advancing age.

Multi-joint Coordination

Multi-joint movements are not as smooth and coordinated for older adults compared to younger adults. For example, older adults make jerkier movements, which are irregular in their time course, when they draw with the wrist and fingers simultaneously, as opposed to moving just the wrist or just the fingers alone. Similar results are obtained when older adults make reaching movements that require motion of both the elbow and the shoulder joint simultaneously, as opposed to elbow or shoulder single-joint actions. The same pattern of deficits, although to a greater extreme, is seen in deafferented patients who lack proprioception. Patients with cerebellar damage show comparable behaviors, decomposing multi-joint movements into a series of single-joint actions. These findings indicate that coordination difficulties observed in older adults may be due to age-related degeneration of the proprioceptive system and the cerebellum (*see* Touch and Proprioception).

Bimanual Coordination

When individuals are asked to make discrete movements to targets that are short or long distances away, both older and younger adults are more accurate and less variable when they make symmetrical movements (e.g., the two hands move to both short or both long targets) than when they have to make more complex asymmetrical movements (e.g., one hand goes to a short target while the other moves to a long target). However, older adults tend to make more movement errors, are slower to initiate and execute movements, and show greater differences in initiation and termination time between the two hands than younger adults, especially as coordination complexity increases. Older adults also have more difficulty adapting the movement time of each hand to make up for any differences in initiation time.

A typical task used to assess bimanual coordination is the performance of arm extensions and flexions in the horizontal plane, with the two arms either moving 'in-phase' or 'anti-phase'. In-phase movements require subjects to move the arms away and toward the body midline in a mirror-symmetric fashion. The more complex anti-phase pattern requires subjects to move the arms in the same direction (both arms simultaneously toward the right, then the left), asymmetrically about the body midline (see schematic in **Figure 3**). Older adults are slower than young adults for both types of bimanual actions, regardless of whether they are moving at their preferred or maximum speed. Moreover, except when moving at very slow speeds, older adults show greater coordination breakdowns for the

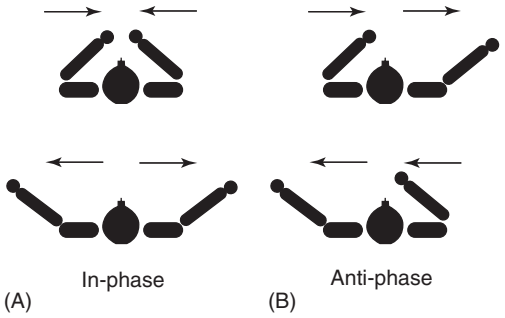

Figure 3 Panel A depicts the 'in-phase' pattern of bimanual movements, while panel B depicts the 'anti-phase' pattern.

anti-phase condition than young adults. These breakdowns are typically associated with a shift from the anti-phase pattern to the easier-to-maintain in-phase pattern.

Learning a novel bimanual coordination pattern is especially difficult for older adults. Even after extensive practice, they show fewer gains than younger adults and, after having learned the task, less long-term retention of the new pattern. These problems are thought to result from older adults' greater difficulty at inhibiting preferred patterns of coordination. At the start of learning a novel coordination task, both young and old subjects will show frequent transitions into preferred modes of coordination. However, older adults take longer to overcome this tendency than younger adults.

Coordination of Transport and Grasp in Prehensile Actions

In recent years, aging research has increasingly emphasized tasks involved in daily living. The appeal of these functional tasks, such as reaching to grasp an object, is that they stress goal-oriented behavior and are highly practiced. Thus, the data obtained provide a better approximation of how aging affects sensorimotor performance. Prehension research paradigms require subjects to reach and grasp objects using either a whole-hand grip (thumb opposite all fingers) for large objects or a precision grip (thumb opposite the index finger) for smaller objects.

Coordination of hand transport and grasp components in prehensile tasks can be examined by determining the correlation between the amplitude and temporal characteristics of wrist and grip. There is conflicting evidence regarding whether there is a breakdown of coordination in prehension in the elderly. One study has reported such correlations as higher for younger adults than for older adults, suggesting that the coupling between the two components becomes less stable with advanced age. However, another investigation has reported only minor changes with age in the coordination of the two components. Nevertheless, both studies showed that, when expressed as a percentage of movement duration, maximum grip aperture occurred earlier for the elderly adults. The slowing of movement and the longer deceleration times imply that the elderly may rely to a greater extent on on-line feedback, suggesting perhaps a greater emphasis on accuracy. This is further supported by the observation that some older subjects slightly close and then reopen the grip aperture during wrist transport. This suggests that the elderly may place greater reliance on visual feedback during the reach, consistent with the finding that removal of visual feedback has a more detrimental effect on the elderly than on the young.

Changes in Timing Abilities with Age

Coordinated action requires the precise temporal synchronization of multiple body segments. One contribution to age-related declines in coordination across a variety of tasks may be deterioration in timing abilities with advancing age due to slowing down or increased variability of an internal pacemaker mechanism. Tasks that require absolute duration judgments, such as verbally estimating the length of a presented duration or trying to produce a duration that matches a verbal label, do not involve having to synchronize to an external pacemaker; therefore, one would expect them to be highly sensitive to internal pacemaker changes with aging. Studies using this type of task to assess the effects of age on timing ability have led to mixed results. Those in which the interval duration to be timed was filled with some other task reveal age-related slowing, while those using empty intervals show an increase in pacemaker speed with age. One possible reason for these differing results is that older adults may be more sensitive to the attentional demands of timing tasks than younger adults. In particular, attention may modulate how representations of temporal durations are formed from the workings of the internal pacemaker. If an appropriate amount of attention cannot be focused on the timing of a specific duration, the number of pacemaker pulses that are stored as a representation of that duration will be affected. Support for this view comes from studies that reveal that older adults have more trouble than younger adults on tasks with high attentional demands (e.g., having to time multiple durations concurrently or having to process compound stimuli). However, when concurrent tasks involve non-temporal processing, increases in attentional demands do not always lead to worse performance in older as compared to younger adults.

Neural Correlates of Age-Related Changes in Motor Performance

The use of brain imaging techniques to study changes in cognitive processes with age has contributed greatly to our understanding of the aging brain. Some studies have demonstrated that performance deficits are correlated with reduced activation for older adults in the brain regions that support task performance in young adults. Studies have also reported additional brain activation in older adults in regions that are not associated with task performance in young adults ('dedifferentiation'). In some cases,

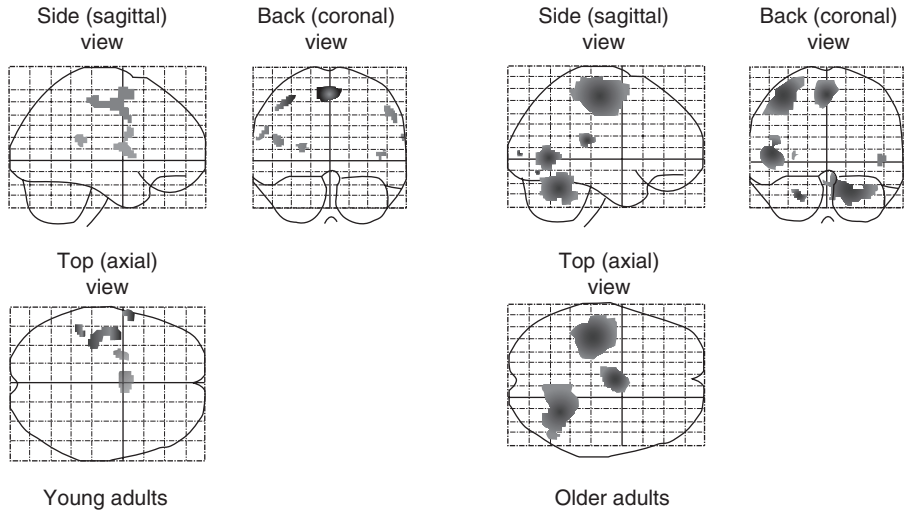

Figure 4 Brain activation during right hand tapping for young (left display) and older (right display) adults. Tapping consistency was equal between the two subject groups. Older adults exhibit more activation in the sensory and motor cortical and subcortical regions of the brain than younger adults.

this activation occurs in the absence of activity in regions that were identified as task-relevant in young adults. This pattern of brain activity has been termed substitution. In some studies, the additional activation has been observed in the contralateral homologous region to that typically observed in young adults. This contralateral activation often appears to be compensatory, as it is correlated with better task performance in older adults. This activation has been termed HAROLD, or hemispheric asymmetry reduction in older adults. In contrast to this view of dedifferentiation as compensatory, it is also possible that nonselective recruitment of additional brain regions in older adults reflects dysfunctional processes.

There are only a few examples in the literature in which brain imaging techniques have been utilized to study motor control processes in the aging brain. While the results of these studies hint that bilateral compensatory brain activation may be seen in motor as well as cognitive tasks, only one of these examples correlated performance with brain activation. In this study, subjects performed a manual choice reaction time task while in a functional magnetic resonance imaging (fMRI) brain scanner. Older subjects had a greater area of activation in brain regions associated with task performance in the young adults (motor and sensory cortical and subcortical brain regions). Older adults also recruited additional areas that serve sensory, motor, and attention functions. For older subjects, greater activation in several of the motor cortical areas was correlated with faster reaction times, supporting the idea that recruitment of additional brain regions may serve a compensatory function, aiding motor performance. Data demonstrating that older adults recruit more brain regions than young adults to perform a given task are presented in **Figure 4**. Engagement of additional brain regions may be a general compensatory strategy that occurs in older adults. However, it remains unclear how this additional recruitment affects the available neural resources for performance of more complex tasks in older adults (*see* Neuroimaging (MRI, PET)).

Are the Observed Deficits Transitory in Nature?

Elderly subjects often perform more poorly on unfamiliar than on familiar tasks. Such a finding raises the possibility that the observed age differences are not fundamental limitations of the motor system. These limitations should be thought of as transitory effects rather than primary deficits if practice can reduce or eliminate the observed age differences (*see* Skill Acquisition and Physical Therapy and Rehabilitation).

Motor Learning in Older Adults

Multiple studies have demonstrated that older adults do not acquire new motor skills as quickly as young adults. Even following additional practice, performance for the older adults typically does not reach the same levels as for young adults. One theory suggests that this may be due to older adults requiring more time to consolidate new information into a long-term motor memory. An alternative theory suggests that older adults may have difficulty integrating cognitive strategies into the motor learning process. One exception to the oft-reported finding of skill acquisition

deficits in elderly adults is the learning of very simple motor tasks, such as repetitive finger tapping. Older adults show substantial gains with practice on these tasks, effectively eliminating age-related performance deficits. In addition, age-related motor declines seem to be absent for skills that have been practiced extensively throughout the lifetime. For example, highly skilled typists and skilled musicians seem to be relatively immune to age-related performance changes in their tasks of expertise.

Variability of Movement

In some tasks, older adults have been shown to reduce their variability of performance with practice. For example, some research has shown that both elderly and young subjects become more accurate at a triangle-tracing task that utilizes opposition forces between the thumb and index finger over 3 days of practice. The elderly subjects did improve more than the young from day 1 to day 2, but then their performance stabilized by day 3. The young subjects, however, improved in a linear fashion across all 3 days. Moreover, the elderly have shown reduced movement-to-movement variability in an arm aiming task after practice. Following practice on an arm aiming task, young adults show the capacity to increase their initial ballistic submovement to reach a given target in a single effort. Older adults failed to show this adaptation. Instead, elderly adults demonstrate greater efficiency using feedback information in making their corrections. The increased reliance on these feedback mechanisms does, however, lead the elderly to be slower and more variable than the young on these maximal speed aiming tasks. From these two examples it appears that the elderly can reduce the variability in their movements, but typically do not reduce it to the level exhibited by young subjects following practice.

Movement Trajectories

There appear to be marginal effects of practice on many of the kinematic features of simple arm movements for the elderly. Young subjects exhibit a decline in the percentage of the movement spent in the deceleration phase and in the variability of arm position at the end of the acceleration phase with practice. Older adults, however, do not demonstrate changes in the acceleration to deceleration phase ratio, even after extended practice.

It appears that practice can be beneficial for improving the motor performance of older adults on some tasks. In some cases, older subjects improve at a faster rate than the young. However, performance levels often fail to reach those of younger adults, even after extended practice. This implies that the deficits observed in motor performance are a result of limitations in the capacity of the aging motor system.

Conclusions

It is evident that older adults exhibit decreased motor performance abilities with advanced aging that may affect their capacity to perform everyday activities. Age-related deficits include a slowing of movement time and in alterations in control that suggest a greater reliance on feedback. An inability to precisely control and modulate force appears to be a limiting factor in a variety of activities. Coordination deficits may arise due to age-related declines in proprioception and/or timing. These reduced capabilities can be somewhat mitigated with practice, but in general performance levels seldom reach those of younger adults.

See also: Neuroimaging (MRI, PET); Neuromuscular System; Physical Therapy and Rehabilitation; Skill Acquisition; Touch and Proprioception; Vision.

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N

Narrative and Aging

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Glossary

Lifestory – An amalgam of memory and imagination, fact and fiction, inseparable from identity Narrative Practices Forms of self-telling, life genres, ways of life, or storying styles that underlie how we talk about and therefore how we experience our lives.

Narratives – Biographical materials including life-stories, self-reports, autobiographies, memoirs, thematic interviews, diaries and letters.

Introduction

A stereotype of older adults is that, given the right conditions, they welcome the opportunity to talk about their lives, or tell their stories. The fact that people's stories are important to them can be taken as a starting point for discussing the intricate relationship between narratives and aging. The various matters that this discussion raises can be grouped in terms of the commonsense structure of any story: having a beginning, middle, and end. Accordingly, this article (1) outlines influences that have given rise to interest in narrative in the past, particularly in relation to aging; (2) considers issues of ongoing relevance in relation to the definition, dynamics, and dilemmas of narrative; and finally (3) identifies areas within gerontological theory and practice to which a narrative perspective can continue to be applied in the future.

Past Influences

The impetus for the growth of interest in the topic of narrative and aging is the realization that the emphasis in gerontology has been placed on what could be called the outside of aging. By this is meant aspects of aging that are more or less visible or measurable, such as age-related changes in our bodies and our cognitive abilities, or the impact of an aging population on societal structures, health-care policy, pensions, and the like. An almost exclusive employment of experimental and statistical methods in research on aging has led, however, to dissatisfaction on the part of many gerontologists and a sense that vital dimensions of aging are being overlooked. The increasing utilization of narrative approaches in gerontological circles thus bears out the insight that it is necessary to inquire into aging from the inside. Further, narratives or a narrative perspective is particularly suited to the investigation of biographical aging. Narratives, in this context, thus comprise a range of biographical materials, including life stories, self-reports, subjective or guided autobiographies, memoirs, thematic interviews, personal documents such as diaries and letters, and archival data. In the case of literary gerontology, narratives include stories or images of aging in films, novels, and other works of art. The idea of using narrative methods to study the individual originated with John Stuart Mill in the 1850s and Wilhelm Wundt in Europe. Sigmund Freud also employed narratively constructed case histories in his work. The distinction between nomothetic and idiographic methods, a standard distinction in psychology, was first used by William Stern, and later by Gordon Allport. In the 1920s, George Stanley Hall used autobiographies in studying adolescence, and Henry Murray is considered a classic source of narrative approaches in the field of personality psychology.

The precursors to narrative approaches in aging from a sociological perspective are the symbolic interactionist perspective of the Chicago School and the work of Wilhelm Dilthey. John Dollard is a final figure worthy of mention in this context, as he introduced the life history method into sociology in the 1930s. Moving from this first historical period, authors who are considered to be part of the gerontology context itself include Erik Erikson, Charlotte Buhler, and Bernice Neugarten. Another significant figure is Hans Thomae, for his contribution to the Bonn Longitudinal Study. This study

employed both narrative and experimental methods, an integrative approach that is becoming more common in contemporary gerontology. In terms of methods, an important approach that is widely used in aging research is that of grounded theory, developed by Glaser and Strauss. This approach has found its way into most gerontology textbooks with its contribution to the understanding of the nurse–patient biographical encounter, care of the dying, geriatric units, and other aging studies.

In the 1970s narrative studies of aging included Lowenthal, Thurner, and Chiriboga's *Four Stages of Life*; Levinson, Darrow, Klein, Levinson, and McKee's *Seasons of a Man's Life*; Gail Sheehy's *Passages*; and Roger Gould's *Transformations: Growth and Change in Adult Life*. In sociology, the main figures at this time were Bertaux and Bertaux-Wiame, with their studies of the professional life of the French baker, which appeared in *Biography and Society*.

During the 1980s a number of key texts appeared that highlighted the methodological aspects of narrative research. These works have had a strong influence on research, specifically in the field of aging. Included in this group are William Runyan's *Life History and Psychobiography* and, very significantly, Donald Polkinghorne's *Narrative Knowing and the Human Sciences*, Theodore Sarbin's *Narrative Psychology*, and Jerome Bruner's *Actual Minds, Possible Worlds* and *Acts of Meaning*.

To complete this selected history of narrative in the study of aging, reaching to the present, pertinent works include Sharon Kaufman's *The Ageless Self*, Peter Coleman's *Ageing and Reminiscence Processes*, Erik and Joan Erikson's *Vital Involvement in Old Age,* and Barbara Myerhoff's *Remembered Lives*. The contemporary scene has witnessed an intense growth of interest in narratives and adult development. Important works in this context are Dan McAdams' *The Stories We Live By*, Jaber Gubrium's *Speaking of Life*, Ken Gergen's *The Saturated Self*, William Randall's *The Stories We Are*, Ruth Ray's *Beyond Nostalgia*, and Robert Atkinson's *The Gift of Stories*. Special issues of a number of journals, as well as several edited volumes, have also appeared.

The use of narratives in the field of aging is part of the larger postmodern turn in the human sciences, with its critique of traditional notions of truth, meaning, power, and authority. From this point of view, all phenomena may be seen as based on language, narrative, and interpretation. It is also a central assumption of this view that such phenomena as human behavior, identity, and relationships are, at least to some degree, socially constructed.

The use of narratives in gerontology is, moreover, a multidisciplinary enterprise. It is also characterized by a wide range of methodological approaches that share the common conviction that human nature is storied and by a wide range of topics of interest. A partial list of these topics includes widowhood, frailty, chronic pain, dementia, holocaust trauma, longitudinal studies, age identity, wisdom, spirituality, end-of-life issues, and caregiving.

Present Issues

Insofar as the inside of aging, or inner aging, can be explored via narratives, or by adopting a narrative approach, three broad issues emerge as requiring ongoing consideration: the definition of narrative, the dynamics of narrative, and the dilemmas that are involved in understanding narratives of, or about, aging selves.

Definitions of Narrative

The term narrative has a number of references, which can easily be confused. First, it refers to a certain type of data, that is, stories as opposed to statistics, or anecdotal comments on particular themes as opposed to scores on tests or yes–no answers on survey questionnaires. Second, it refers to a variety of methods that are employed both for collecting such data and for analyzing them afterward. These methods are central to qualitative research in general and to research on topics like reminiscence in particular, as well as to such areas as qualitative gerontology, narrative gerontology, feminist gerontology, and literary gerontology. Third, narrative can refer to a theoretical construct, namely, personal narrative or self-narrative or simply 'the story of my life.' However, the relationship between life and the story – or, more accurately, stories – that one tells or internalizes is an intricate one. Indeed, some theorists collapse the two terms into one and speak of lifestory, seeing it as an amalgam of memory and imagination, fact and fiction, that is inseparable from identity. Fourth, narrative can refer to an entire intellectual paradigm, or root metaphor, whereby humans are viewed as fundamentally story-telling creatures and narrative as our primary mode of knowing, of making sense of our world. As such, it represents an essential heuristic to employ when exploring the experience of aging. It is on narrative as construct and as paradigm that the rest of this article is focused.

Dynamics of Narrative

Narrative is widely used as a more technical term for story. Indeed, wherever the narrative turn has had an

impact, the two are typically (though not always accurately) equated. Yet story itself, while a common enough construct, is scarcely easy to unpack, as literary theorists can certainly attest. It can be argued, however, that a story in its most basic sense is someone telling somebody about someone doing something. This basic formulation goes to the heart of the structural dynamics of narrative, whatever type is considered: fictional, historical, or lived. At the same time, it points to several intertwining issues – or dilemmas – of an epistemological, ethical, ontological nature to which those dynamics give rise, and with which an examination of the narrative dimensions of aging obliges us to wrestle.

Someone Telling Someone A story is told by someone to someone. As such, it involves both a narrator (or narrators) and author (or authors), though in some stories the two seem as one. Obviously, it involves the act of narration as well, which can be carried out from various points of view, ranging from third person to first and omniscient to unreliable; from various vantage points in time, ranging from recent to remote; and with various narrative tones, ranging from optimism to pessimism and tragedy to irony. In short, stories are recounted according to genres. Also, they are told within particular settings and thus, explicitly or implicitly, to particular audiences, although with some stories, such as those one tells oneself, narrator and audience, author and reader, seem to be fused.

About Somebody Doing Something A story is always about something. In the most basic sense, it is about actions or events that affect, or are affected by, its characters. Typically, it entails an element of tension or conflict, plus its resolution, with the movement from one to the other comprising the plot. In essence, no conflict, no plot; and no plot, no story. In turn, plots often have subplots and, obviously or not, are divided into chapters, episodes, or scenes. They also reflect the unfolding of various themes. Great stories are about a number of themes at once, from love to war, faith to philosophy, history to ethics. As already noted, this makes the analysis of narratives an interdisciplinary endeavor. It also means that stories are never innocent but are told to accomplish a range of agendas, often several at once. In general, authors attempt to persuade readers, and tellers attempt to influence listeners. At the same time, listeners influence tellers, and can determine to a powerful degree what tellers tell and how they tell it.

Given these basic dynamics of narrative, it is apparent that when people tell the story of their life, they are, paradoxically, author, character, narrator, and reader all at once. Moreover, they are all of these within the story. Yet each of these roles is an identifiable rhetorical function of a self that, from a narrative perspective, is multiple or dialogical in nature – self as narrator, self as character, and so forth. Such a paradox is one of the many complexities, questions, or issues that accompany the lifestory construct. Over time, for instance, we may play a range of characters within our own lifestory: major and minor, central and supporting. As well, the events that are central to that story, or that comprise its plot, are events in our own lives. In that respect, we never just tell our stories; we live them. However, as narrator of those same events, we may not be entirely or consistently reliable. There is an inherent opacity associated with the living and telling of lives. In addition, a variety of life themes can surface across our life span, related to particular developmental tasks or particular characters we are living at particular times, and some of these themes recur. Finally, a lifestory is not one story so much as numerous stories in one, as is a novel. Indeed, because a lifestory both is unique to a particular individual and is emplotted – that is, is not merely a chronicle of event after event – then we could perhaps refer to the novelty of lives.

Dilemmas of Narrative

There are a cluster of dilemmas or issues that the construct of personal narrative brings into focus. They can be discussed in terms of time, interpretation, intertextuality, truth, and transformation.

Time To paraphrase Kierkegaard's famous observation, we live our lives forward but understand them backward. This is an inescapable paradox of story-time, which, on the inside of aging, we may live by much more so than clock time. In remembering or reviewing our lives, as in reading a story, we understand the past through the lens of the present, and we experience the present in light of the future (or futures) that we anticipate. In turn, we look to the future on the basis of what we recall having experienced in the past, or what we wish we had experienced, or what we are grateful we did not. Our sense of the past always includes stories about what might have been. In terms of time, autobiographical consciousness is thus a complex phenomenon, though fundamentally retrospective in nature. We read our lifestory from the end looking back to the beginning.

Interpretation Narrative, it is argued, is our principal mode of making meaning. It is by telling stories about events that we make sense of them, even if it is

only ourselves whom we tell. Human beings are interpretive beings, or hermeneutical beings. But the meanings we make of – or read into – events in our life will eventually be overlain, if not replaced, by the meanings we make of those events, and other events, tomorrow. Thus, like a kind of biographical capital, lifestory meaning continually changes and accumulates (or thickens) with time. This accumulation is an element of what some theorists call narrative development, which unlike physical development has no necessary end point. As with a great novel, even though the story ends, there is no end of meaning to be gleaned from it. Its meaning is indeterminate. As self-readers, however, perhaps most of us tend to underread our lifestories, or else overread particular passages while effectively ignoring the rest.

Intertextuality Making and remaking meaning is possible because, ontologically, we are creatures of language, and therefore of text. We can understand our lives only by textualizing them. Until we die, this textualization continues. Thus, our lives are open texts. Such textualizing occurs not in a vacuum, however, but amid a variety of interwoven contexts. These include family or community, culture, profession or discipline, gender, or creed and can be thought of as so many larger stories or narrative environments in which our personal stories are shaped, or misshaped, to the degree such contexts are, say, sexist or ageist or otherwise restrictive in nature. Such larger stories constitute interpretive communities that mediate what in narrative circles are referred to as narrative practices, forms of self-telling, life genres, ways of life, or storying styles. These underlie how we talk about and therefore experience our lives. Moreover, they influence what we remember, how we remember it, and how we feel about life in general, inasmuch as emotions have narrative roots. For better or worse, we textualize our lives, or our lives are (in part) socially constructed, through a constantly changing network of intertextual relationships and biographical encounters with others. These others co-author us into being (as we do them), though some, such as parents or therapists, structure our stories in especially deliberate ways. In a similar vein, and as noted by literary gerontologists, our stories are structured and our worldviews shaped through interactions with actual texts too, such as the novels we read, movies we watch, songs we hear, or, depending on our interests, works of history, religion, or science we may study.

Truth Because we make meaning of events by textualizing them – both at the time they occur and each time we recall them thereafter – and because this textualizing takes place amid particular relationships and environments, each of which affects the direction our tellings are slanted, the meaning-making process involves continual selecting and editing. However, unlike the text of a novel, which is written in black and white and in that sense is solid, the text of our life is highly unstable. With each telling and reading it is different, depending on who we are telling what, or for what reasons we are reading it. That we interpret the past through the present and future, and so on, only contributes to this instability. The point is that there is no straightforward connection between our life events and the stories we tell or internalize about them. The claim that people's stories are important to them is not a claim about the events of their lives per se but about how they interpret those events that, however creatively, they are able to recount. Inasmuch as our lifestory is true, its truth is less historical than narrative in nature. In this sense, lifestories not only contain answers to certain questions, but also are answers, insofar as they reflect what is meaningful to a particular person. In narrative research and practice, these meanings provide an understanding of a specific phenomenon and a basis for intervention.

Further, we can all tell multiple stories about our lives, but never the whole story. The whole story is never available for reading either, although particular episodes, or signature stories, may persist in standing out. In addition to being backward, autobiographical consciousness is incomplete, which renders the construct of autobiographical memory problematic. Remembering is not a matter of passively, let alone accurately, recording what happened and then recalling it later. It is always, in part, imagining. There is no such thing as the truth, the whole truth, and nothing but the truth.

Transformation Because we perceive the ever-thickening past through the lens of the ever-changing present in the light of an ever-shortening future, we are continually rewriting our selves. We are not just storying our lives but on some level are restorying them, too. As open texts, to which new events are steadily being added, our lifestories are capable of a number of possible tellings and readings, retellings and rereadings – depending on the contexts in which we tell them and live them. Indeed, from a narrative perspective, possibility as much as facticity is the hallmark of human experience. This suggests the particular possibility that in later life we can experience significant restorying, if not re-genre-ation, meaning a fundamental reformulation of the stories by which we understand who we are. Another possibility is that some may submit prematurely to a sort of narrative foreclosure and assume that – once

retired, for instance – their story is over, that there is little to be read in it, that nothing further of significance awaits them except death itself. Others, operating from a different master narrative, may view death not as the end but as the beginning, a segue to the next new chapter.

Future Applications

By considering the dynamics and dilemmas of self-narratives, we can appreciate the complexity of narrative development in later life, plus the implications of a narrative perspective for numerous areas of continuing interest for gerontological theory and practice. Some of these areas are discussed in relation to four interwoven categories: therapy (broadly defined), ethics, aesthetics, and spirituality.

Therapy

As mentioned previously, autobiographical memory is temporally complex, continually revisable, and inseparable from imagination. In short, the text of the past is far from fixed, but is capable of multiple versions, some more positive or life-affirming than others, depending on which metaphors are enlisted to access it and which themes are singled out to interpret it. Insofar as people's mental health is entwined with how they have storied their past, this is a critical realization, and an implicit starting point for most therapeutic interventions. From a narrative perspective, people are always, in principle, capable of changing their stories and thus, however modestly, of changing their attitudes, behaviors, and identities – even in later life. For example, such restorying could be triggered by becoming aware that a particular subplot, chapter, or theme in one's life, such as having cancer, being widowed, or getting older, is not the whole story of who one is. In fact, narrative research bears this insight out, namely, that it is necessary to understand a particular phenomenon in light of an entire lifestory. Among the interventions relevant here are reminiscence therapy, life review therapy, narrative therapy, psychotherapy, psychodrama, guided autobiography, and various forms of clinical care.

Ethics

Therapy is a controlled, highly intentional form of telling and listening. Yet even in everyday life, listeners unwittingly co-author tellers' lives and to a degree are agents of restorying. Little focus has been given, however, to the role played by the listening we experience in shaping the stories we tell and live. The nature, function, and ethics of good listening in later life deserve particular attention, especially in light of the possibility that, through bereavement, disability, or institutionalization, many older adults experience a dramatic constriction of the narrative environments in which they are accustomed to telling and interpreting their lives. This can contribute to their gradual 'destorying' just when they may otherwise be capable of a quality of narrative development that is perhaps possible only in later life, such as discovering and creating their unique wisdom story. Gerontologists could benefit, then, from considering what conditions would foster a wisdom environment in which, as in guided autobiography, older people are able to engage in deep telling and close reading of their lifestories, perhaps particularly their signature stories, and in deep listening to the stories of others. Such opportunities can be the route to integrating and even extending older people's sense of identity by expanding their repertoire of approaches to interpreting their life texts, thereby enriching their appreciation of the multiplicity of meanings, or truths, those texts contain. Two further ethical issues need to be noted: one is the necessity of acknowledging that everyone has or is a story, even the person who for whatever reason is unable to tell it in ways that others can readily comprehend, for example, someone who is dementing or dying. A second issue is that people should never be forced to tell their story against their wishes, however convinced we are that the process will be good for them.

Aesthetics

Across the centuries, numerous traditions have promoted understandings of, if not recipes for, the art of living. A narrative perspective holds the potential for acknowledging or re-covering the aesthetics of growing old, or what some refer to as the poetics of aging, whereby lives are viewed as quasi-literary texts that it behooves us to examine for the multiple meanings they can carry. The intersection of narrative gerontology and literary theory is thus an area that is currently being explored. A related area, of equal importance when approached from the perspective of therapy or ethics, concerns what criteria are appropriate for evaluating a good story in later life, as well as a satisfactory generativity script – that is, a picture of how one wants one's story to end. Such considerations could help link discussions of the aesthetics of aging with discussions of, for example, its spiritual dimensions.

Spirituality

Spirituality, broadly defined, concerns making meaning in, or of, our lives. However, spirituality is

experienced through, not despite, the stories of our lives. Thus, from a narrative perspective, spirituality and wisdom are closely linked. This experience can also involve an identification with elements of particular grand master narratives. However much their authority may have become eroded, such narratives are philosophical, political, or religious traditions, such as Christianity, communism, or existentialism, that provide plot lines, metaphors, and themes for making meaning of difficult life events, dramatic transitions, or the course of life as a whole, including death. Accordingly, a narrative perspective on spirituality in later life can shed light on such things as gerotranscendence. Gerotranscendence entails an expanded sense of time, past, present, and future, and a yearning for a story of the world that can encompass life and death alike, one that may even transcend the terms of the master narratives into which one has been born. Such yearning may also find expression in the urge felt by many older adults to understand their place in the broader narrative of the human community and to appreciate their roots as members of a particular family, community, or culture. Linked to this urge is generativity: the impulse to contribute to the well-being of the next generation and, in some small way, to bridge the gap between history and posterity.

Conclusion

The use of narratives in gerontology is expanding in relation to all four of the understandings of narrative indicated earlier, namely, as data, method, construct, and paradigm. Moreover, the range of topics that are of interest to narratively inclined gerontologists continues to expand. Contemporary gerontology is increasingly characterized by a collaboration among many approaches with the aim to understand both the inside and the outside of the complex and multifaceted story of aging.

See also: Life Events; Life Review; Memory; Reminiscence.

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Network Analysis

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Glossary

Anchor – The central person within the network; the person providing information on who belongs to his or her network.

Full Personal Network – Network in which information is available on all the network relationships; also referred to as a complete network.

Network Analysis – Analytical methods used to compute measures of network structure and content.

Network Content – The type of interaction that takes place within pairs of network members.

Network Delineation – Procedure used to identify the personal network.

Network Structure – Aspects of the total network derived from combining features of individual relationships and the linkages between these relationships.

Personal Network – The group of persons (network members) with whom anchor has a direct relationship.

Star Personal Network – Network in which information is available on relationships between network members and the focal individual; also referred to as an ego-centric network.

Introduction

The personal networks of older people reflect their social opportunities and personal choices to maintain a specific set of relationships with relatives, neighbors, friends, acquaintances, and so on. Network analysis is the method used to identify and examine the structural and functional features of the network of the older adult. The conceptualization and operationalization of the personal network depend on the subject of research. Five approaches to defining personal network membership are presented and discussed. The five approaches differ regarding the part of the personal network that is mapped, and result in networks of different sizes and compositions. Regardless of the type of network delineation, a distinction can be drawn between the star network (data available on relationships with the focal person) and the full network (data available on all the network relationships). Features of the structure and content of both types of personal networks are presented. Finally, network analysis methods are presented and discussed, including ways to analyze hierarchical databases.

Aging and the Personal Network

The Personal Network of Older Adults: An Introduction

The personal network occupies an important place in the lives of individuals. The mere existence of a certain number of relationships has been shown to have beneficial effects; regular interaction with network members (children, relatives, neighbors, friends, and fellow members of organizations) enhances the feeling of being socially integrated and decreases feelings of loneliness. The positive effects of the network are also reflected in better health and a longer life.

Old age has often been associated with loneliness and with social isolation. However, numerous studies have shown over the past decades that the large majority of older adults have at least a few relationships available. The networks of older people usually encompass both kin and non-kin with whom regular contact is maintained. In general, the core of the network consists of close kin (e.g., spouse and children, siblings, parents) and close friends. Depending on the identification method of the network, other network members such as extended kin, neighbors, (former) co-workers, acquaintances, members from organizations, and so on may also be identified. The younger old who are socially active in many parts of society and who experience few physical restrictions in general have large networks that are composed of a large number of non-kin. The oldest old, who often experienced life transitions such as widowhood, retirement, and a decline in physical mobility, usually have smaller networks that enclose network members that are emotionally close (children, friends) or geographically close (neighbors).

In addition to the mere presence of relationships, interaction with others is important for daily functioning, coping with life events, and maintaining well-being. Feelings, information, services, and material goods can be exchanged between two individuals. These exchanges are often assumed to be supportive in nature. The support provided by network members helps protect individuals from experiencing negative outcomes, helps them in their efforts to improve their situation, and helps them respond to adverse events.

Social researchers have too often studied the personal relationships of individuals without taking the linkages between various network members into account. However, network members do not function independently of each other. It is crucial to regard the interaction between the focal individual and one network member in relation to the interaction with other network members. For example, which of the adult children is to provide support for an elderly parent might be the outcome of a family meeting at which they decide to take turns in caregiving. The study of personal relationships evolves into the study of the personal network if relationships are viewed as part of a large network and if linkages between these relationships are also taken into account. Combining the features of individual relationships leads to insight into the structural aspects of the network. Examples of structural aspects are size, composition (e.g., proportion of kin), and homogeneity (e.g., proportion of same-sex network members). Information regarding the content of the network can be obtained by aggregating the qualities of the individual relationships. Examples of network content are network interaction (e.g., number of frequent contacts) and support intensity (e.g., proportion of instrumentally supportive relationships).

The Impact of Aging on the Personal Network

Old age is often associated with shrinking network size and relationship losses. In the early days of social gerontology, these social losses were considered due to the loss of societal engagement and social activities. Currently, the diversity and changes in the personal network in later life can be understood from three different perspectives: (1) the changes in roles and transitions in later life, (2) the changes in the expected returns from relationships within the network, and (3) individual proactive management of personal relationships.

From early childhood to old age, an individual is surrounded by a variety of persons with whom he or she develops relationships, a so-called 'convoy' of relationships. During the life course some relationships end due to major (role) transitions (divorce, death of the spouse) or minor transitions (moving, changing jobs, entering or leaving organizations), while others may last a lifetime. New members may enter the network as a result of (re)marriage, a new job, or becoming a parent or grandparent. Thus, people enter old age with a personal network that reflects earlier transitions affecting their opportunities and individual choices to maintain and develop relationships. During old age, a phase lasting no less than 20 years for many people, people are in general in a position to exercise greater choices in their relationships. Unfettered by employment obligations and the responsibility for children at home, they generally have greater opportunities to organize and structure their social lives. On the other hand, a decline in health may impose restrictions upon older adults' capacities to engage in interaction with others. Hearing and memory problems can limit conversational exchanges, and reduced physical mobility can limit participation in shared activities. Role changes and restricted capacities in later life lead to a decrease in non-kin relationships and the growing importance of family relationships in the network.

From the second perspective, based on exchange theory, network change in later life results from changes within specific relationships. People constantly evaluate their relationships and prefer balanced support, i.e., they give support with the expectation of receiving something in return at some time. If the receiving party is not able to return the support and it is clear that this will not change in the future, the exchange of support may decline. Older adults may become more dependent on others, lacking the ability to perform certain tasks themselves. The existing balance in their relationships may be disrupted, introducing strain and discomfort. Imbalance results in the decline of supportive exchanges with older adults, in particular with less close relationships. Imbalance does not always end in the termination of a relationship, however, as overbenefiting of needy older adults can be normatively accepted and even desirable.

From the third perspective, based on the socioemotional selectivity theory, network change results from changes in an individual's motivation. With increasing age, the time horizon is limited, and emotional regulation becomes the most important drive for social interaction. As a result, older people disengage from peripheral relationships because the emotional engagement with core network relationships is more rewarding. This explains the selective shrinking in network size with age. People feeling near to death deliberately discontinue their less close relationships, reduce the emotional closeness with many others, and increase the emotional closeness with core network members such as kin and friends.

It can be concluded that dynamics in the personal networks of older people are related to changes in situational and personal characteristics. A network is the result of macro-social trends that create individual opportunities to maintain a personal network, but it also reflects individual transitions, relationship standards, and personal characteristics. In studying the networks of elderly people, it is recommended to relate changes in network features to changes in situational as well as personal characteristics of the elderly.

Personal Network Delineation

Methods for Network Delineation

A personal network is defined in general as the group of persons (network members) with whom a focal individual (anchor) has a direct relationship. There are various methods of delineating the social network. Some methods are based on the content of the relationships, some are based on the affective value of the ties, and other methods use the formal role relationship as a criterion for network membership. Research interests determine which method is used and which part of the larger social network will be identified.

The following five major methods can be used to identify networks of the aged: (1) the affective method, (2) the role relation method, (3) the exchange method, (4) the interactive method, and (5) the domain contact method. The five methods are conceptually unique and map different parts of the personal network. **Table 1** provides a summary of the main features of the five methods.

Table 1 Overview of network delineation methods

	Affective	*Role relation*	*Exchange*	*Interactive*	*Domain contact*
Conceptual definition	Network of significant others (affect based)	Network of formal role relations (role based)	Network of relations in which significant interactions occur (content based)	Network of persons with whom social interaction exists (contact based)	Network of socially active and important relations (contact and affect based)
Name generator(s) (examples)	"Who do you feel close to?"	"Name your spouse, children, neighbors, colleagues, friends"	"Who do you discuss personal problems with?" and "Who helps you with daily chores?"	"Name the persons you have contacted today for at least 10 minutes"	For each role relation (e.g., children, neighbors): "Who do you have regular contact with and who is also important to you?"
Number of questions asked	One or two	Depending on the roles of interest: five to seven	Three to 20	One (repeated every day for a certain period of time)	One for each role relation of interest (about seven)
Limits on period of time	No	No	Yes (past 6 months, past year)	Yes (2 weeks, one month, etc.)	No
Network size	Small (about three to nine)	Depends on the number of roles of interest	Large (10 to 22)	Large (16 to 26)	Medium (13 to 15)
Proportion of kin	Large (50 to 78%)	Depends on the roles of interest	Low (19 to 48%)	Low	Medium to large (66%)

The Affective Method

Conceptual framework The affective method identifies members who are of affective value to the focal individual, in other words, significant others or intimates. The underlying assumption is that these network members are potentially important sources of support for the focal individual. The method is commonly used by researchers who are interested in the 'psychological network,' defined as persons to whom the focal person feels attached.

Name generator This type of network is identified by asking one question: "Who do you feel close to?" or "Who are the persons who are important to you?" Some researchers set limits to the number of names to be mentioned; others apply a time frame (e.g., within the past 6 months). Sometimes a distinction is drawn in the degree of importance or the level of closeness of the network members.

Network features Typical of the affective network is a small size (about five to nine members), a large proportion of (close) kin (about 50 to 80%), a large number of long-standing relationships, and many supportive exchanges within the ties. The stability of this type of network is high, mostly because relationships that are stable, like those with close relatives and best friends, are cited.

Evaluation Crucial to this method is the subjective nature of the name generator. People are asked to evaluate relationships in terms of importance or closeness. This evaluation may be shaded by norms and obligations to mention relationships that are supposed to be important, for example, those with the spouse and children. A person is less inclined to mention relationships that are potentially supportive but not very important to the individual, for example, those with neighbors or colleagues. In addition, it need not be necessary to include persons with whom one interacts on a regular basis. As a result, this type of network can not be used to indicate the degree of social participation or integration of the focal individual. This type of network is positively related to the degree of well-being and negatively to feelings of loneliness of the central person. The major advantage of this method is that it has proven to be a robust method by yielding similar types of networks in different samples.

Role Relation Method

Conceptual framework The role relation method defines network membership purely on the basis of the formal role relationship maintained with the focal individual. Role relationships are derived from status variables such as marital status, employment status, type of living arrangements, friendship, and family status. The network accordingly includes the

partner, children, co-workers, friends, and members of the household. The underlying assumption is that the formal role relationship reflects norms and obligations with respect to the content of the relationship. The mere existence of relationships is expected to protect an individual from social isolation, illness, and loneliness.

Name generator Researchers using the role relation method do not always use a name generator. Inquiring after marital status, parental status, or job status will suffice if one is interested in the availability of a spouse, children, or co-workers. Researchers interested in the additional features of the role relationships have to use name generators. Examples include "Who is your partner?", "Who is your best friend?", and "Could you name two fellow members of your organizations?" The type of role relationship that is identified depends on the research objectives. Sometimes limits to the number of names to be mentioned are set.

Network features The size as well as other features of the network are completely dependent on the name generators used. The stability of the role network is high, since formal role relationships are not likely to change over a short period of time.

Evaluation The advantages of this method are that it is very easy to administer and it uses an objective measure for the identification of network members. Researchers interested in the social integration of individuals will be able to use this method successfully. One disadvantage is that relationships that have no formal role but that may nevertheless be important or supportive might be overlooked. The use of the role relation method in studies on support networks may therefore be limited.

Exchange Method

Conceptual framework The exchange method assumes that the relationships in which significant interaction occurs with network members are among the most important ones. Within this significant interaction, a regular exchange of emotional support, instrumental assistance, and material goods takes place. This interaction is considered to be of a supportive nature.

Name generator The exchange method uses several questions (usually six to ten) to identify members with whom significant interaction occurs. Examples include "Who do you talk about personal problems with?", "Who do you discuss problems at work with?", "Who helps you with daily chores around the house?", and "Who takes care of you if you are ill?" Often a limit to the number of names to be identified in response to each question is set. The number of questions asked is related to the number of persons to be identified, but there is a certain limit. It has been noted that asking five questions about different types of support (emotional and instrumental support and companionship) identifies about 80–85% of the persons who are mapped with ten questions. Some researchers distinguish between questions indicating the receipt of support ("Who helps you with daily chores?") and questions indicating the provision of support ("Who do you help with daily chores?"). This results in a larger number of identified persons compared to non-directive questioning about exchange relations.

Network features The typical exchange network is rather large, varying from about ten to 20 names. The proportion of kin within the network is rather low, varying from 35 to 50%. In general, the exchange network contains many relationships that are socially active at the time of measurement. A relatively large proportion of more superficial relationships is identified, based on a (temporary) sharing of the same workplace, organization membership, neighborhood, etc. The stability of the exchange network is relatively low compared to the affective and role relation networks, since many unstable non-kin relationships are identified.

Evaluation The exchange method is easy to administer and of a rather objective nature. The interactions are specific and not multi-interpretable. The exchange method can map different parts of the network. In contrast to the affective method, non-kin relationships are more likely to be identified. One disadvantage is that ties that are potentially supportive but not actually supportive at that moment are overlooked. In addition, persons one is socially involved with but with whom no significant interactions are exchanged (e.g., more distant relatives) are also excluded from this network. Crucial to this method is the fact that it focuses on the content of a tie rather than the formal role relationship or the degree of contact frequency.

The Interactive Method

Conceptual framework The interactive method identifies the persons with whom one engages in social interaction within a given period of time (e.g., 2 weeks, a month). The assumption is that the interactive network indicates the degree of social participation. It is found to be unrelated to support or well-being.

Name generator The interactive method requires a systematic recording of the people one has contact with on a daily basis. Usually this is done by having respondents maintain a diary or by contacting them daily by telephone. Respondents have to indicate whom they interacted with on that day for at least 10 minutes.

Network features The size of the interactive network depends on the period used for monitoring social interaction. The longer the period, the more different persons are identified. The interactive network may contain a large proportion of non-kin relationships, depending on the living situation of the respondent (married, employed, with children, etc.). The interaction network is apt to be sensitive to changes in daily contacts. Many superficial contacts that are part of the interaction network in a given period may not be included in another period of time.

Evaluation The interactive network is a good indicator of the degree of social participation, since it records daily social interaction. Comparing this method to other methods reveals a very small overlap between the networks. The affective and exchange networks are far more psychological, and their members usually do not meet every day. However, enlarging the monitoring period of the interactive network will eventually decrease the differences with the exchange network. A major advantage of daily monitoring is that it provides a reliable picture of the social interaction of the respondents.

The Domain Contact Method

Conceptual framework The domain contact method combines the different roles an individual performs with the frequency of contact and the importance of the relationships as criteria for the identification of network members. The main objective of this method is to identify the socially active relationships in the larger network. A central assumption is that this type of network constitutes the structural vehicle for the ties in which various types of support can be exchanged. In this line of reasoning, the potential or actual support exchanged is not a criteria for delineation, but an object of research on the delineation of the personal network.

Name generator Network members are identified in various domains of the network, e.g., household members (including the spouse), children and their partners, other relatives, neighbors, school or job acquaintances (including voluntary jobs), members of organizations (sport, church, political parties), and others (friends, acquaintances). All the household members are included in the network. As to the other domains, the respondents are asked, "Name the persons (e.g., in your neighborhood) you have frequent contact with and who are also important to you." No limits are set on the number of names to be mentioned.

Network features The domain contact network is medium to large (an average of 13 members, ranging from 0 to 75), with about two-thirds of the relationships being with relatives. Since that contact frequency is used as a criterion for identification, the average contact frequency with these network members is relatively high, between about once every 2 weeks and weekly.

Evaluation Using several criteria for network membership leads to a medium-sized network (compared to the smaller affective network and the larger exchange network) that contains a large range of role relationships. The method combines objective criteria (role relationship and contact frequency) and subjective criteria (importance) for the delineation of network relationships. As a result, the domain contact network indicates the actual degree of social participation as well as the availability of potentially supportive relationships.

Choices in Network Research

The examination of the personal networks of older adults requires several choices to be made by the researcher beforehand. The first choice concerns the type of method to be used for network delineation. This necessitates a clear description of the research objective. Usually, two types of research objectives can be distinguished: (1) the network has to indicate the degree of social participation of older adults, and (2) the network has to reflect the actual support reservoir of older adults. The first type of objective requires the use of the role relation method, the interactive method, or the domain contact method in the delineation of the network. The affective method and the exchange method are more appropriate if one has the second type of objective in mind.

The second choice within network research focuses on how many network members and relationships additional information will be collected on. In most network research (particularly large surveys), there is no time to collect information on all the network members who are identified. Some researchers have solved this time problem by setting limits to the number of names to be identified by the name generator. However, limits of this kind distort the

identification of the network because they leave uncertainty about the true size of the personal network. Since network size is crucial for the calculation of other structural and functional network features (e.g., proportion of kin), it is strongly recommended to set no limits on the number of persons to be identified. A better solution is to add an extra objective criterion such as contact frequency or traveling distance to the identification procedures. If interview time is of the essence, additional information can be asked about a selection of the network members. The selection criterion can either be objective, e.g., the ten persons contacted most frequently, or subjective, e.g., the six persons who are the most important. The disadvantage of the subjective option is that respondents have to choose between certain network members, which may be a difficult task.

The third choice in network research pertains to the type of information to be collected on some or all of the identified network members. Again, this choice is guided by the research objectives. Yet there seems to be a general consensus among network researchers that it is advisable to collect information on the type of relationship and sex of as many network members as possible. Researchers interested in the degree of social participation also inquire about the contact frequency with each network member, whereas support researchers are more interested in the support exchanged within the relationship.

A final choice the network researcher has to make involves who is to serve as a respondent in the study. Usually, the information on network members and relationships is obtained only from the focal individual, the anchor of the network. The identified network is then called a star network, and only information on the ties between the anchor and his or her network members is available (**Figure 1**). Yet it is also possible to include network members as respondents and ask them about the tie characteristics with the anchor and with the other identified members of the network. If members of a personal network report about identified ties with other network members, data are available on a full network (**Figure 2**).

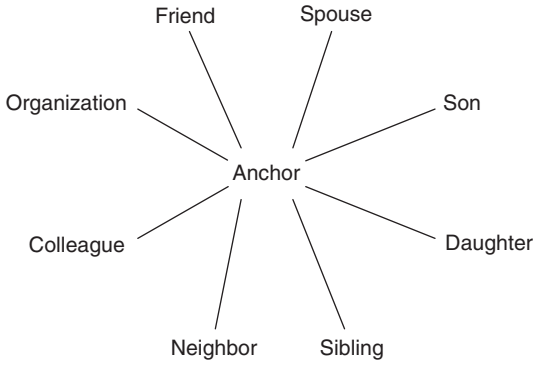

Figure 1 Graphic representation of a star network.

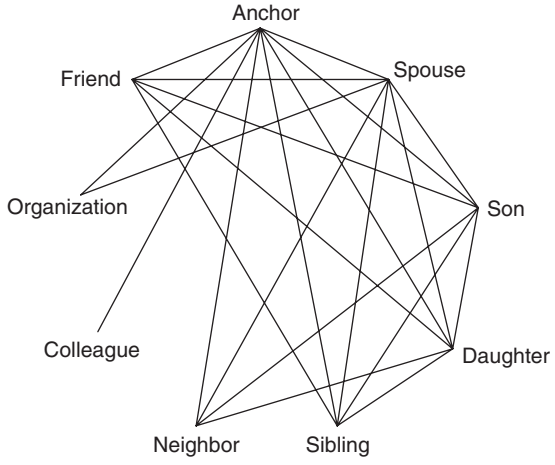

Figure 2 Graphic representation of a full network.

Features of the Personal Network

In a star network, the older adult is the focal person, the anchor. All the features of the network and the relationships can be linked with his or her behavior and state of mind. The following sections provide an overview of features of the network structure and content associated with aging. As people age, these aspects of the network are subject to changes and are therefore relevant to the study of the networks of older adults. **Tables 2** and **3** give examples of network structure and content based on information about relationship features.

Network Structure

The size of the network indicates how many relationships one is involved in, whether affect-based, role-based, or contact-based. Involvement in a larger network is associated with a larger degree of social participation and a greater exchange of support and well-being.

The network composition indicates the available proportions of kin and non-kin. The distinction between kin and non-kin is often too global, and it is wise to differentiate between relationships with a spouse, children, other kin, neighbors, friends, and other non-kin.

If information on the personal characteristics of the network members is available, it is possible to compute the homogeneity of the network with respect to sex, age, parental status, and so forth. It has often been reported that individuals like to associate with people who have similar backgrounds and who

Table 2 Features of network structure

Network structure	*Operationalization at the network level*	*Information on the dyad*	*Information on the network member*
Size	Total number of identified network members		
Composition	E.g., number of children, friends; proportion of kin	Role or type of relationship	
Homogeneity	E.g., total number of females in the network; percentage of members within the same age category	Similarity between characteristics of anchor and network member: e.g., same-sex or cross-sex	E.g., sex, age, race, partner status, employment status
Density	Total number of pairs who know each other of the total number of available pairs		How many of the other network members are known
Stability	Average years of network membership	Duration of the relationship	
Role complexity	Number of multiplex relationships	Number of different roles shared with the network member	
Geographical dispersion	E.g., number of persons living within 15 minutes; mean traveling time	Traveling time from anchor to network member	

Table 3 Features of the network content

Network content	*Operationalization at the network level*	*Information on the dyad*
Interaction	E.g., proportion of network members contacted at least weekly, mean frequency	Frequency of contact
Support intensity	E.g., total amount of emotional support received and given, proportion of ties with large social support intensity	Receiving and giving support (emotional, instrumental, social, material goods)
Support complexity	E.g., total number of multiplex relationships	Exchange of one versus more types of support
Reciprocity	E.g., average number of reciprocal relationships, proportion of unbalanced ties, ratio of given and received support	Balance between giving and receiving of support

are assumed to have similar life experiences. In particular, non-kin network members are expected to exhibit marked similarities in sex, age, and level of education with the focal individual, resulting in a large homogeneous non-kin network.

The density of the network refers to the interconnectedness between network members. Large networks usually have a low overall density, meaning that fewer network members interact with each other without the anchor being present. However, large networks may also contain specific parts that are very high in density (neighbors or close relatives). Networks that are low in density are generally found with younger persons who are highly educated and participate in various social organizations that are only loosely connected to each other, if at all. Small networks usually have a high density and are generally more prevalent among elderly people with a relatively low level of education. Dense networks are generally composed of persons who have been interacting for many years, indicating a high stability within the network.

Network members may have more than one formal role relationship with the focal person. A neighbor may also be a friend, and a second-degree relative may also be a member of the same club. At the network level, role complexity is indicated by the number of uniplex (one formal role) or multiplex relationships. Networks with a high role complexity are usually also small and densely knit.

The geographical dispersion within the network indicates the extent to which network members live in the same neighborhood or region by the proportion of network members who live less than 15 minutes' drive away. The geographical dispersion of the network demonstrates the availability of potential supporters in the vicinity of the older adult.

Content of the Network

The overall interaction of the older adult with the network members is often used as a token of social participation. Network interaction may vary among different parts of the network. Interaction is higher

with the spouse, children, and neighbors than it is with distant relatives and acquaintances. The more frequently one interacts with network members, the more likely the exchange of support. The support intensity of the network refers to the exchange of support between all the network members and the focal person. Various types of support can be distinguished: emotional support, instrumental support, social support (companionship), material support, and so on. Furthermore, a distinction can be drawn between giving and receiving support. The types of support vary among the types of relationships, and among older men and women. Men are known to exchange instrumental support, whereas women are known to give and receive emotional support to an old age.

The exchange of two or more types of support within the network relationships indicates the support complexity of the network. Some network members provide emotional as well as instrumental support, whereas others exchange only material goods.

Last, the balance between the overall provision and receipt of support indicates the support reciprocity within the network. In general, elderly people receive more support than they provide. This is particularly the case after there is a strong decline in their physical capacities. Giving and receiving support is usually more balanced for women than men. An unbalanced support network has a negative impact on the well-being of the elderly. The imbalance created by being in debt to many network members leads to feelings of guilt, whereas providing support to many relatives and friends without receiving much in return can lead to feelings of being exploited.

Methods of Network Analysis

Data Storage

Network data are hierarchically constructed. There are two levels of star network data. The elderly person as the anchor of the network is the higher level, with such characteristics as sex, age, network size, and well-being. Inside of it, characteristics of the network members such as sex, and characteristics of their relationships with each other such as traveling time and support received by the elderly person are on the lower level. There are three levels of full network data: the network as a whole, for example, its size; the characteristics of the network members including the elderly person; and the features of their relationships with each other. The data are stored in accordance with this hierarchic structure.

Analysis of Network Data

One of the attractions of having network data at one's disposal is that data on different levels can be linked to each other. There are two methods for simultaneously analyzing the data on both levels: aggregation and disaggregation.

In aggregation, data from the lower level of the separate network members and/or relationships are transferred to the higher level of the elderly person. For each elderly person, a researcher can take the mean of the contact frequency within his or her relationships and introduce the average contact frequency as variable in an analysis to explain the differences in the well-being of elderly people. A variant on aggregation as the average frequency of contact across relationships would be to count the number of network members with whom there is contact at least once a week. Statistical software has capacities for aggregation of this kind.

In disaggregation, data from the higher level of the elderly person are related to the lower level of the separate network members and/or relationships, for example, when the researcher wants to find out whether more support is exchanged in same-sex relationships than in cross-sex relationships. Data from different cases are not independent of each other, so this violates an assumption of many analysis techniques. The application of multi-level analysis is appropriate. In this analysis technique, a linear regression equation is formulated for explaining variance in a variable on the lower level from the perspective of other variables on the lower level. The support received by an elderly person is then predicted on the basis of, for example, the sex of the network member and of the elderly person. Interaction effects can be added to the model. A crucial aspect is that the magnitude of the effect of explanatory variables on the relationship level may differ between respondents. Therefore, the intercept as well as the slopes of the different independent variables in this equation are then explained with different regression equations from the perspective of independent variables on the higher level, such as the age and health of the elderly person. Multi-level analysis techniques are available as specific software.

Summary and Conclusions

The personal network is considered a social resource and is important for daily functioning, coping with life events, and maintaining well-being. The impact of aging on the personal network becomes evident in the changes within the structure as well as the content of the network. The personal network of the elderly can be studied with different objectives. The researcher can focus on the content of the network, e.g., the relation between support and well-being, or on structural aspects of the network, e.g., the relation of

marital status to its size, composition, and density. In every network study, several methodological choices are made beforehand: which network delineation method is to be used, whether additional information is to be collected on some or all of the identified network members, which information is to be collected, and who will provide this information (only the older adult or all the members of the network).

See also: Bereavement and Loss; Caregiving and Caring; Demography; Economics: Society; Hearing; Life Course; Loneliness; Memory; Psychological Well-Being; Social Networks, Support, and Integration.

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Neuroimaging (MRI, PET)

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Glossary

Activation Imaging – An imaging technique that identifies brain regions that show increased cerebral blood flow, which is tightly coupled to neural activity, during ingoing mental operations.

Functional Magnetic Resonance Imaging (fMRI) – An imaging technique that monitors blood flow indirectly and requires comparison of two states such as memory task performance and a baseline control task.

Magnetic Resonance Imaging (MRI) – An imaging technique that allows for observation of structural differences in the brain, noninvasively.

Positron Emission Tomography (PET) – An imaging technique that monitors glucose metabolism and blood flow that can identify functional brain changes in patients.

Introduction

Neuroimaging is widely used in the evaluation of Alzheimer's disease (AD). Traditionally, imaging in AD has been used to exclude other diseases and neurological conditions that produce similar cognitive symptoms. Recently, however, neuroimaging has been explored for its potential in predicting clinical outcomes in subjects before the onset of AD or as surrogate markers for monitoring the course of treatment. While these experimental uses tend to be more exploratory than of current clinical application, the diagnosis of AD has unquestionably been advanced

with the inclusion of neuroimaging. In particular, positron emission tomography (PET) imaging has gained wider usage, as characteristic patterns of hypometabolism appear strongly related to AD. As the science progresses, several imaging measures may aid not only in diagnosis of current disease but also in prediction of incipient disease. Imaging is predicted to impact the field of AD management in three ways: first, by increasing the specificity of disease diagnosis; second, by allowing AD to be detected earlier in patients with only mild cognitive impairment or, even earlier along the disease continuum, in patients without apparent clinical symptoms; and third, by following disease progression and treatment once it is diagnosed in predementia stages. However, the clinical application of imaging in AD has not yet been fully maximized and, in the future, the contribution of neuroimaging is likely to be critical to the understanding of both pathophysiology and therapeutic intervention.

PET Studies in AD

PET has proven to be a sensitive and specific tool for identifying functional brain changes in patients with AD as well as those in preclinical stages, including genetic risk and mild cognitive impairment (MCI). PET uses positron-emitting radionucleotides (commonly used isotopes include oxygen-15 [^{15}O], nitrogen-13 [^{13}N], carbon-11 [^{11}C], and fluorine-18 [^{18}F]) to monitor both glucose metabolism and blood flow after these molecules enter the central venous system and are detected by crystal scintillation detectors in the PET scanner. The most commonly used ligand binds ^{18}F to deoxyglucose, producing the moderately long (110 min) half-life compound ^{18}FDG, which measures resting glucose metabolism with great sensitivity. ^{18}FDG imaging of resting metabolism in AD patients demonstrates a consistent pattern of reduced blood flow and metabolism throughout the middle temporal region, cingulate cortex, and the parietotemporal association cortex. This pattern of altered blood flow and metabolism spreads in a superior to inferior fashion, beginning typically in the superior parietal cortex, and then spreading inferiorly and anteriorly to involve the inferior parietal, superior temporal, and prefrontal cortices (**Figure 1**). As the disease progresses, frontal cortices become more affected, while the primary motor and sensory areas remain preserved until the final stages of the disease, following closely the pattern of plaque and tangle distribution as detailed by Braak and Braak in their landmark 1991 paper. The extent of hypometabolism correlates with the severity of cognitive impairment and often shows right/left hemispheric asymmetry. More recent studies using higher-resolution PET scanning have reported marked hypometabolism of the hippocampal head and amygdala in AD. A longitudinal study determined that measuring regional brain metabolism in subjects presenting with early signs of dementia was a sensitive indicator of

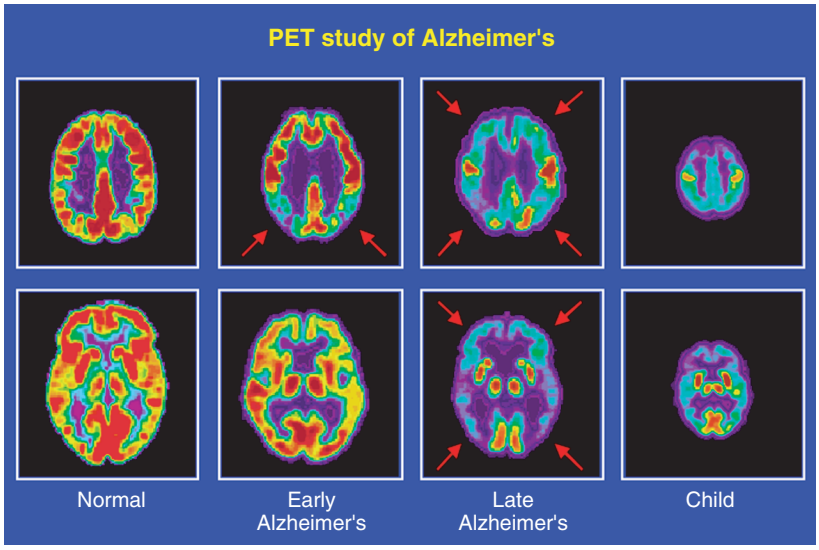

Figure 1 A PET study of glucose metabolism in Alzheimer's disease. The early Alzheimer's study was performed at the stage of questionable Alzheimer's disease and illustrates the characteristic metabolic deficits of Alzheimer's in the parietal and temporal memory centers of the brain (arrows). Over time, the metabolic deficit spreads throughout the brain. At the late stage of disease, metabolic function of the brain in Alzheimer's is similar to that of the child shown to far right, which corresponds to their similar behavior and functional capacity. Reproduced with permission from Small G (2005) Alzheimer's disease and other deserting disorders. In: Sadock BJ and Sadock UA (Eds.) *Comprehensive Textbook of Psychiatry*, 8th edn., pp. 3687–3693. Baltimore MD: Williams & Wilkins.

subsequent AD. PET identified AD patients with a sensitivity of 94% and a specificity of 73%.

PET Studies in MCI

Patients with MCI, considered to be of considerable clinical interest because of the 50% rate of conversion from MCI to AD over a 4-year period, typically show hypometabolic patterns similar to AD patients but reduced in magnitude and extent. Current clinical practices now focus on MCI as a prodromal phase of AD. The reduced metabolism seen in MCI patients is typically restricted to the medial temporal cortex. In longitudinal studies of MCI patients, the conversion of MCI to AD may be predicted by specific patterns of hypometabolism. For example, in those MCI patients destined to convert to AD within a year, hypometabolic patterns were detected within the temporoparietal association areas as well as the posterior cingulate cortex. However, the reduction of cerebral metabolism within prefrontal cortical areas was the most highly correlated with the transition from MCI to AD. This was interpreted to represent the course of disease progression. Compared to normal controls, MCI subjects demonstrate reduced cortical metabolism primarily in temporal regions including the entorhinal cortex (ERC), the hippocampus, the lateral temporal lobe, as well as the dorsolateral frontal cortex. In addition, the reduction of glucose metabolism at baseline in normal subjects within the ERC predicted with high accuracy (84%) the decline from normal aging to MCI. Overall, these findings suggest the utility of reduced glucose metabolism within the medial temporal lobe (MTL) as a predictive measure of decline from MCI to AD. This also suggests the possibility of the recognition of AD in non-demented stages, leading to more effective disease intervention.

PET Studies and Genetic Risk

Identifying genetic polymorphisms that are overrepresented in AD has proven a successful way of identifying individuals with a significant risk for AD and, in combination with imaging, may increase our ability to detect AD in preclinical stages. In particular, discovery of the relationship between the Apolipoprotein E e4 allelle (APOE-4) allele on chromosome 19 and AD is one of the best-replicated findings in complex human genetics. APOE-4 significantly decreases the age of onset of the disease in a dose-dependent manner and is associated with higher β-amyloid (Aβ) plaque burden.

Early imaging studies made use of the newly discovered gene to reveal subtle alterations in brain function among non-demented carriers. In a study designed to monitor progression of metabolic changes over time, Small and colleagues used PET imaging, in combination with genotyping, to reveal subtle alterations in cerebral metabolism among older, non-demented carriers of APOE-4 in 2000. They found a decline in left posterior cingulate metabolism and inferior parietal and lateral temporal regions in APOE-4 carriers after a 2-year follow-up PET study. The authors suggested that combining PET imaging with genetic risk factors provides a method for preclinical detection of AD that will assist in response monitoring during experimental treatments (**Figure 2**). Several other groups have also identified alterations in glucose metabolism similar to AD patterns in genetic risk subjects without clinically apparently cognitive impairment. This type of study holds the potential for increasing the efficacy of therapeutic treatments.

Activation Imaging with PET

An alternate approach to imaging brain function in AD uses activation imaging, in which subjects perform a cognitive task, such as a memory test, in comparison to a control or resting state, during scanning. These methods identify brain regions that show increased cerebral blood flow (CBF), which is tightly coupled to neural activity, during ongoing mental operations. In principle, brain regions with impaired neural activity will show less CBF when engaged in a task than those unaffected and have the potential for identifying deficits more sensitively. In practice, however, activation imaging is more complicated: first, PET ligands used in activation imaging, typically H_2[15-O], have a short half life, necessary for experiments involving multiple conditions but producing images with significantly lower signal, and thus reduced ability to detect differences among individuals. In addition, activation studies have shown evidence of increased brain activity in some regions, likely attributed to compensation. For instance, in normal subjects, increasing task difficulty also increases regional CBF (rCBF) in regions critical for the particular task performance, and individuals with less cognitive ability appear to show an increase in brain metabolism. Thus, it is not surprising that activation imaging studies with PET have yielded mixed results in studies of AD.

In a study of normal aging published in 1993, scientists compared CBF in older and younger subjects while they performed visuoperceptual tasks. Both older and younger subjects showed similar CBF increases in superior visual pathways; however, young subjects showed greater activation of prestriate cortex,

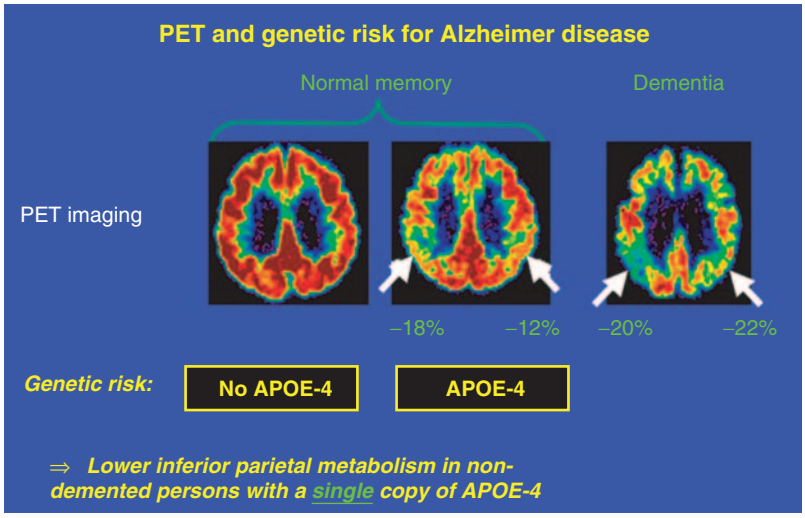

Figure 2 The first two PET scans were performed on people in their 60s – both had only minor memory complaints. This shows how someone with normal memory performance may have deficits in brain function revealed by the PET scan, especially if they have the APOE-4 genetic risk for Alzheimer's disease. Adapted from Small GW, Ercoli LM, Silverman DH, *et al.* (2000) Cerebral metabolic and cognitive decline in persons at genetic risk for Alzheimer's disease. *Proceedings of the National Academy of Sciences USA* 97(11): 6037–6042.

while older subjects had greater rCBF increases in visual recognition areas in occipito-temporal cortex. Older subjects also had greater activity in the prefrontal cortex, which may be consistent with their need for increased effort to perform the task. Comparing older controls with AD, the same group reported that the pattern of rCBF activation observed in normal older subjects during a perceptual matching task is maintained in patients with AD of mild to moderate severity. Such results are similar to other findings that normalized glucose metabolism in occipital areas increases during behavioral task performance in patients with AD, but does not differ in magnitude from that in controls. In contrast, Kessler and associates reported a similar pattern of regional glucose utilization in 1991 in patients with AD and control subjects during a visual recognition task, with patients demonstrating increases of lower magnitude than control subjects. However, these subjects were more demented, which could explain the reduced activation.

Several authors have suggested that subjects use compensatory strategies that produce increased activity in regions less affected by the disease. Small and colleagues found an association between patients' use of mnemonics and cerebral glucose metabolism; subjects who used more frequent mnemonic strategies had lower rates of glucose metabolism in inferior frontal cortex. The results suggest that in early AD, patients attempt to compensate for subtle cognitive impairments by employing compensatory strategies that invoke the use of more intact cortical structures.

Amyloid Imaging

There is a keen interest in developing more direct measures of AD-specific pathology, which has led to the emergence of several new PET ligands to measure amyloid deposition. Amyloid plaques, which are composed of Aβ, and neurofibrillary tangles (NFTs) are the pathological hallmarks of AD. NFTs are correlated with the stage of AD, and both pathological deposits appear before symptoms show themselves, perhaps decades before. This observation suggests that these deposits may be a good early marker for the disease. Based on the presence of diffuse plaques in neurologically normal individuals, it may be that Aβ accumulation precedes other pathological features of AD. Controversy exists as to the chain of events in this Aβ cascade. However, evidence suggests that accumulation and aggregation of Aβ is related to brain inflammation, disruption of neuronal metabolism and ionic homeostasis, altered neuronal kinase/phosphatase activities resulting in hyperphosphorylation of tau and paired helical filament (PHF) formation, and finally, neuronal death in AD. Thus, a biological marker of NFTs and plaques as well as specific hippocampal neural function would have great potential for early detection of AD.

[^{18}F]DDNP

In 2002, results were published that used 2-(1-{6-(2-[F-18]fluoroethyl) (methyl)amino-2-napthyl}ethlidene)malononitrile ([^{18}F]DDNP) as a molecular

imaging probe for the localization of pathological disease features in living AD patients (NFTs and senile plaques) using PET (**Figure 3**). [^{18}F]DDNP binds to plaques and tangles in a manner analogous to receptor–ligand interactions. However, it is likely that the binding reflects a complex process involving multiple binding sites. Receptor–ligand interactions are governed by the dissociation constant, binding affinity constant, and receptor density constant. PET visualization of *in vivo* probe binding to brain receptor sites with a receptor density of approximately 20 nM requires dissociation constant values in the nanomolar range in order to get specific binding. [^{18}F]DDNP has two such sites. In addition, it crosses the blood–brain barrier in proportion to blood flow in a manner similar to ^{18}FDG. The scientists who conducted the study measured the relative residence time (RRT) of the molecular imaging probe in areas known to be associated with AD (the subiculum, entorhinal, and transentorhinal regions; hippocampus; basal temporal lobe; basal frontal lobe; isocortical regions; supramarginal and supratemporal gyri regions) compared to the pons, an area known to have limited lesions due to AD. Higher RRT times denote higher NFT (receptor) density based on binding to the probe, [^{18}F]DDNP, and were also associated with poorer memory performances as measured by the Mini-Mental State Examination (MMSE). Specifically, the hippocampus–amygdala–entorhinal regions were associated with the highest RRT values and generally matched the lowest MMSE scores. It is noteworthy that the authors validated [^{18}F]DDNP binding to senile plaques and NFTs through postmortem analysis of an AD patient.

PIB

Another promising compound, 2-(4′methylaminophenyl)-6-hydroxy-benzothiazole (referred to as Pittsburg compound B or PIB) showed promising results in labeling Aβ deposits. Multiphoton microscopy was used to capitalize on the fluorescent properties of PIB and observe the contrast agent crossing the blood–brain barrier within seconds and specifically label amyloid plaques and cerebral amyloid angiopathy, or protein deposits in blood vessels, within minutes. The compound was used in transgenic mice models of Aβ deposition (Tg2576 and PDAPP mouse lines), indicating the labeling was not specific to one model of the disease. The first human PIB study demonstrated a robust difference between the retention pattern of PIB in AD patients and the healthy controls. The AD

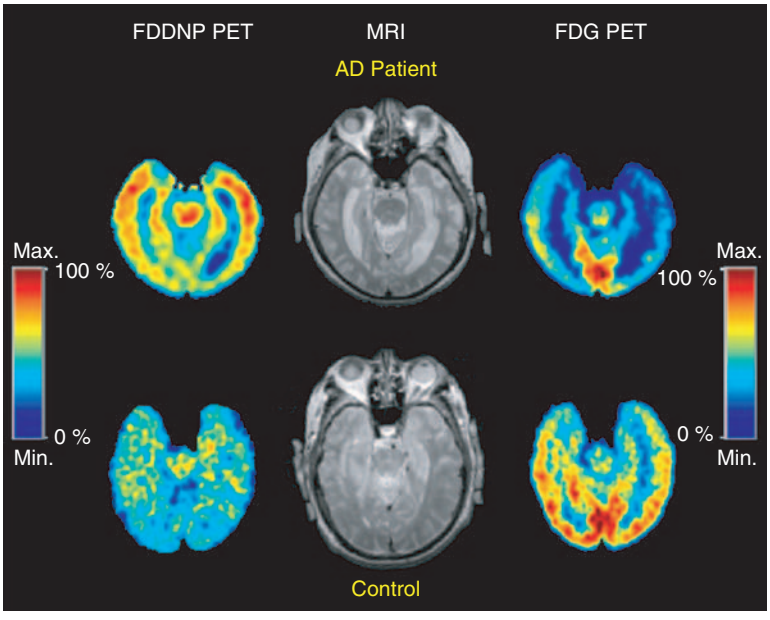

Figure 3 FDDNP PET, MRI, and FDG PET images of an AD and control normal subjects. The FDDNP PET of the Alzheimer's patients (AD; upper scans) shows increased signal (red) in temporal memory regions compared with the control (below). The FDDNP chemical marker is attracted to the plaques and tangles in the brain, which is the physical evidence of Alzheimer's disease in the living patient. The FDG PET shows glucose metabolism indicating how well the neurons are firing. In the Alzheimer's case, the FDG PET shows decreased neuronal activity in the brain regions where FDDNP shows increased activity (i.e., high concentrations of plaques and tangles). The MRI scans show brain structure but no signal for plaques and tangles. Reproduced with permission from Shoghi-Jadid K *et al.* (2002) Localization of neurofibrillary tangles and beta-amyloid plagues in the brains of living patients with Alzheimer's disease. *American Journal of Geriatric Psychiatry* 10(1): 24–35.

patients showed marked retention of PIB in association areas known to contain large amount of amyloid in AD. In areas that remain relatively unaffected by amyloid deposition in AD, however, the control subjects and AD patients showed equivalent retention rates of the amyloid marker. These areas included white matter, pons, and cerebellum. The authors suggested that the study demonstrated the ability of the PET tracer to provide quantitative information on amyloid deposits in living patients. They also suggested the utility of this technique as an *in vivo* technique to assess the efficacy of anti-amyloid drug studies as novel therapies are developed.

[^{18}F]MPPF

The cell loss caused by the neuropathological processes in AD mostly occurs in the vulnerable populations of large pyramidal neurons in the cortex. These neurons form the neuronal circuits responsible for memory and cognition. Serotonin 1A (5-HT1A) receptors are primarily located in limbic areas, particularly those temporal lobe areas affected in early stages of AD. Pyramidal neurons in the hippocampus have high levels of 5-HT1A receptors expressed on their cell bodies through which they receive modulatory serotonergic inputs, suggesting that quantification of receptor density would be useful in monitoring neuronal loss within the MTL in AD. The loss of these pyramidal neurons in the hippocampus has been correlated with 5-HT1A receptor densities. Partial antagonism of 5-HT1A affects cholinergic transmission and affects memory as well. These receptors may be mapped in the hippocampus and other brain areas by using [^{18}F]MPPF, a selective molecular imaging probe that permits the quantification of 5-HT1A receptor densities in the human brain with PET. Mapping of these receptors has been shown *in vivo* in both the rat model and the human brain. Labeling with the ligand in humans matches the known distribution of 5-HT1A receptors, with high binding in the hippocampus, cingulate cortex, entorhinal cortex, dorsal raphe nucleus, and interpeduncular nucleus and low binding in the cerebellum.

Recently, the 5-HT1A ligand has been used to measure neural loss in patients with MCI and AD as well as control subjects. Initial [^{18}F]MPPF PET Logan graphical analysis using cerebellum as a reference tissue in AD patients demonstrates the decrease in hippocampal binding (binding potentials [BPs]) by 40–60% when compared with values for control subjects. Based on these results, it is possible that [^{18}F]MPPF may add information about hippocampal neural integrity above measures associated with aging, providing additional clues to changes in AD independent of APOE status.

Structural MRI in AD

Magnetic resonance imaging (MRI) provides an excellent tool for observing structural differences noninvasively. In aging generally, MRI may show enlarged ventricular size and generalized brain atrophy; however, many of these changes may be nonspecific to AD. Thus, among the goals of MRI research in AD are to identify structural changes that appear early in the disease, including preclinical stages, and that are specific to AD as opposed to normal aging or other dementia disorders. In most cases of AD, MRI-evident atrophy of the MTL is markedly disproportionate to the rest of the brain, and most investigators agree that the first brain structure affected in AD is the MTL, making memory decline one of the earliest cognitive symptoms of the disease. Structural brain imaging studies of AD have revealed that measurements of the MTL are the most sensitive and specific to differentiating AD from normal aging. More specifically, reduced hippocampal volume within the MTL was found to provide a sensitive marker for dissociating AD from normal elderly. From these results, MR volumetry measures of the hippocampus were found to be comparable to the accuracy of a pathologically confirmed clinical diagnosis in distinguishing AD patients from healthy elderly controls. Indeed, the prevalence of hippocampal atrophy in advanced AD may be as high as 96%, with no relation to age. Such significantly reduced volumetric measurements found in the temporal lobe were also correlated to declining performance on neuropsychological exams typically used in the diagnosis of AD.

Within the MTL, pathological studies of changes in synaptic integrity, reduction in density, and the formation of neurofibrillary tangles in AD all point to the ERC as the first target of AD. The ERC receives most of its projections from the perirhinal cortex and the parahippocampal cortex, with some input also coming from polymodal cingulate/retrosplenial cortex, orbitofrontal cortex, dorsal superior temporal sulcus, olfactory bulb, and parainsular cortex. The ERC is the gateway to the hippocampal circuit, including dentate gyrus and cornu ammonis subfields (CA1, CA2, and CA3), and the subiculum. Thus, damage to the ERC affects the entire hippocampal memory system. MRI studies specifically measuring the ERC show that reduction in ERC volume appears to precede other MRI changes in AD and MCI. In contrast, studies of non-AD processes in aging suggest a sparing of the ERC with selective targeting of other hippocampal regions.

Patients with MCI display significant hippocampal atrophy when compared to normal aged controls. Among those MCI subjects retroactively examined for correlates to future AD conversion, MRI results revealed that reduced temporal association neocortex volume combined with reduced hippocampal volume may be the best structural predictor for conversion from MCI to AD. These results suggest that volumetric measurements of the subregions within the MTL, including both the entorhinal cortex and the hippocampus, can correctly distinguish MCI patients from healthy controls.

High-Resolution MRI and Advanced Techniques

To determine change in brain structure with MRI, investigators have relied traditionally on volumetry with user-defined region of interest analysis. While such techniques have provided extremely useful data, they typically emphasize whole-brain image acquisition, yielding pixel dimensions that are at best 1–1.2 mm^3. Higher in-plane resolution methods offer many options for exploring subtle structural abnormalities. Such methods are unnecessary for most volumetry studies, since cortical regions are defined by relatively large boundaries (e.g., sulcal landmarks that are 1–2 cm apart). In some subcortical structures, and in particular the hippocampus, this general rule does not hold: the entire width of the hippocampus perpendicular to the long axis is 1 cm or less; most importantly, the structures within the hippocampus (dentate gyrus, CA fields, ERC, and subiculum) are much smaller than that in the perpendicular axis. Of greatest importance is the known heterogeneity of hippocampal function within these substructures. For instance, neural loss in CA fields 1 and 3 is associated specifically with impairments in acquiring new associations. In addition, recent functional imaging studies have suggested specific roles for subiculum, anterior and posterior hippocampus and parahippocampal gyrus. These findings suggest an important need to identify abnormalities in hippocampus structure and function at a finer level than whole-structure volumes.

Recently, some groups have focused on measuring the thickness of the cortical ribbon rather than the global size of the structure. Overall cognitive function in AD patients correlates with synaptic density in lamina III of the frontal and parietal cortices. Such a pattern of neural loss may suggest that the thickness of the cortical ribbon may change prior to the overall volume of the structure. In a recent study, the thickness of the entorhinal cortex was reduced in genetically at-risk normal volunteers with normal performance on psychometric measurement of memory and cognition. Interestingly, the differences between groups remained stable across age; genetic group differences in ERC thickness were as large in the 45-year-old subjects as in the elderly subjects. This may suggest that APOE-4 subjects have a longstanding vulnerability in the ERC; alternatively, loss of subjects to memory complaints and AD in the APOE-4 group may have masked an interaction between age and genetic status. Thompson *et al.* used an automated, voxel-based technique to determine cortical thickness in AD, showing significant thinning in cortices also known to be hypometabolic.

Structural MRI and Genetic Risk

The atrophic patterns seen in AD and MCI using MRI have been found in reduced magnitude in genetic risk subjects. A study of structural MRI scans from early AD subjects genotyped for APOE status revealed that although all AD patients had significant atrophy of the medial temporal structures, atrophy was greatest among those homozygotes for APOE-4. Large decreases in the volume of the entorhinal cortex of AD patients with APOE-4 compared to APOE-3 carriers have been found; this difference is highest for female patients and correlated with memory decline. In APOE-4 subjects without AD, however, no significant differences in gross structural MRI measures, which included sulcal and ventricular enlargement, were found. However, APOE-4 subjects performed worse on neuropsychological tests. In contrast, significant decreases in the size of the entorhinal cortex and hippocampal head in genetically at-risk volunteers with only mild cognitive impairment have also been found. Similarly, hippocampal volume loss in APOE-4 subjects without AD is associated with memory loss. While structural MRI results in asymptomatic genetic risk subjects have been variable, it is possible that MRI may not be sufficiently sensitive to observe changes prior to signs of memory decline. However, based on the presence of prodromal symptoms as measured by other techniques such as PET or fMRI, it is more likely that measures such as whole-structure volume or ventricular size are not sufficiently sensitive to detect group differences. The effects of the APOE-4 allele may be very subtly expressed early in development of the disease (e.g., initially in the entorhinal cortex), making whole-volume measurements of the hippocampus not sufficiently sensitive to detect differences early in progression of the disease. If subtle deterioration occurs on a smaller scale, subregional volumetry, or measuring the volumes of individual areas within the

hippocampus, may be a more useful methodology for the detection of AD pathology.

Monitoring Change

While numerous studies have identified group differences in imaging measures among MCI or at-risk populations, there are very few studies demonstrating the predictive ability of these methods. Absolute measures of hippocampus and ERC size are vulnerable to baseline differences in overall and regional size that are unrelated to decline, as well as to differences in measuring technique. An alternative approach to morphometric analyses uses a rate of change metric, reasoning that the speed with size decreases may more accurately reflect a declining process than a single time point measure. Several groups have taken this approach. Fox and colleagues, in 2004, used automated and semiautomated serial imaging to map atrophic rates and patterns of gray matter loss in AD, MCI, and normal aging, using the rates to successfully differentiate between the groups and as a marker of disease progression. They also suggest the potential usefulness of serial MRI in determining the efficacy of future disease-modifying treatments and detecting disease onset.

With powerful computing hardware, subvoxel image registration allows repeat MRI scans to be precisely digitally overlaid. This makes it easier to assess longitudinal brain change and create detailed maps of degenerative processes. Gray matter loss in AD has been mapped using powerful image analysis techniques to compare gray matter distribution in AD patients' and controls' MRI scans over time. In a longitudinal study published in 2003, a dynamically spreading wave of gray matter loss was detected in the brains of patients with AD, visualizing the loss pattern in four dimensions as it spread over time from temporal and limbic cortices into frontal and occipital brain regions, sparing sensorimotor cortices. These shifting deficits correlated strongly with progressive cognitive decline ($P < 0.0006$). The potential for this technique in calculating exact rates at which AD and control subjects lose gray matter and, therefore, identifying differences between the two may help in identifying patterns of loss in subjects before the onset of clinical AD symptoms.

Activation Imaging and Functional MRI

Functional MRI (fMRI) is another activation imaging technique that offers several distinct advantages over PET, including non-invasion, increased spatial and temporal resolution, and repeatability, as it does not require radiation exposure. This functional imaging procedure monitors blood flow indirectly, taking advantage of the difference in magnetic susceptibility between oxygenated and deoxygenated blood, whose relative concentrations change during neural activity. The resulting MRI signal change defines the blood oxygen level-dependent (BOLD) response. Like activation PET, fMRI requires comparison of at least two states, such as memory task performance and a baseline control task.

fMRI studies have identified a variety of functional activation differences between AD patients, normal elderly volunteers, and other dementias. Differences in neural activation in patients with AD compared to normal elderly controls have been identified during both visual and language processing tasks. It is important to take into consideration subject performance in such studies: if patients are unable to perform tasks with the same level of accuracy as the comparison group, differences in brain activation patterns may reflect those performance differences rather than regional brain pathology. Matching for performance is much easier in preclinical studies of at-risk subjects. An fMRI study of performance-matched normal volunteers who were asymptomatic but at genetic risk for AD took this approach. Despite equal performance on the fMRI task, which required rote memory for unrelated words, the APOE-4 carriers showed large increases in both the magnitude and spatial extent of activation in frontal and parietal neocortex as well as in medial temporal regions. Further, the extent of these fMRI increases correlated with memory decline after a 2-year follow-up. These results were specific to memory challenge; genetic groups performing a very challenging task that did not include an episodic memory component showed no differences in fMRI activation. Similarly, a study by Smith and colleagues, using a word fluency task, also demonstrated a pattern of increased brain activation while maintaining performance in subjects at risk for AD. These results suggest that individuals with incipient cognitive decline might utilize compensatory strategies, drawing on intact brain resources to perform challenging tasks early in the AD process (**Figure 4**).

In contrast, data on impaired subjects suggests that as cognition declines, patients rely increasingly on primary sensory and motor areas that are less affected by the disease. This notion is supported by the findings of Reiman and others that hippocampal volume loss was detected in only those at-risk subjects showing memory decline. It is likely that an observed compensatory response, e.g., an increase in blood flow or glucose metabolism during task performance, will occur before neural loss and subsequent memory decline; in contrast, significant neural

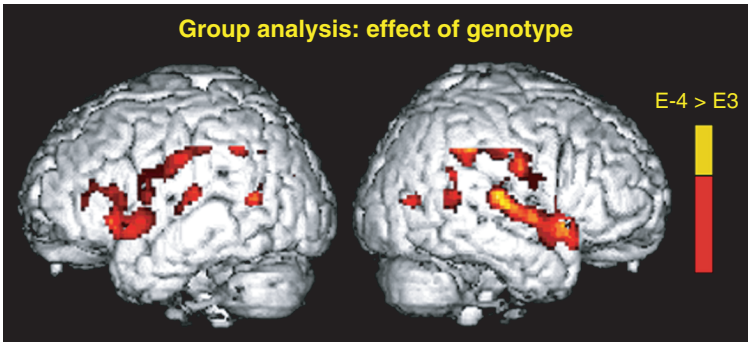

Figure 4 fMRI activation maps of neural activation differences between APOE-4 and APOE-3 subjects during a paired-associate word task. Both the magnitude and the extent of brain activation during memory activation tasks in regions affected by Alzheimer's disease, including the left hippocampal, parietal, and prefrontal regions, were greater among the carriers of the *APOE-4* allele than among the carriers of the *APOE-3* allele. Adapted from Bookheimer SY, Strojwas MH, *et al.* (2000) Patterns of brain activation in people at risk for Alzheimer's disease. *New England Journal of Medicine* 343(7): 450–456.

death in a region will lead to decreased activation. fMRI studies that examined AD patients compared to healthy elderly controls revealed the expected results: reduced activation in the neural network involved in completion of the task. In another fMRI study, patients with mild AD failed to activate either temporal lobe or prefrontal regions that did show activation in normal controls on the same visual learning task.

These studies highlight the potential for detecting functional differences in activation patterns not only between Alzheimer's patients and healthy controls, but also between normal elderly controls before they display cognitive symptoms of the disease. Future applications of this technique may include monitoring functional activation differences longitudinally in a group of normal elderly subjects to assess progression of the disease from the very earliest warning signs (seen as activation differences in the absence of overt memory deficits as measured by neuropsychological tests) to severe deficits in functional activity during later stages of the disease. Taken as a whole, these advances show that functional neuroimaging is developing a prominent role in *in vivo* monitoring of progression of AD (including early detection) and therapeutic intervention.

Effects of Drug Therapies on Neuroimaging

The current standard of clinical care for mild to moderate AD is treatment with cholinesterase inhibitors. Four are currently available: donepezil, tacrine, rivastigmine, and galantamine. These treatments may slow cognitive decline or may reduce the emergence of new behavioral manifestations of the disease but are not considered a cure for the disease. Nevertheless, the prevalence and importance of understanding the physiological effects of these drugs in the treatment of AD is not to be underestimated. In fact, the evaluation of the effects of these drugs on imaging measures has become its own area of specialized research. Some imaging studies suggest the maintenance of cognitive performance by these drugs through increased regional cerebral blood flow. Structurally, the neuroprotective effects of these drugs have been suggested with the finding of reduced atrophy in the hippocampus using MRI. Functionally, fMRI has been used to link the clinically observed increase in cognitive performance after treatment with a cholinesterase inhibitor to altered brain activation. The authors suggest that the modified firing rates observed via differences in the BOLD signal using fMRI reflect altered neurotransmitter status in the brain. Taken as a whole, these studies suggest the utility of neuroimaging measures as a surrogate marker for therapeutic interventions, suggesting the use of imaging measures as a faster measure of pharmacological-induced cognitive benefits in the disease.

Concluding Remarks

The field of neuroimaging in AD is rapidly leaving its indelible mark on the clinical field of AD diagnosis. PET scans have recently been approved for limited coverage under Medicare policies. Several other neuroimaging techniques are promising tools for an earlier diagnosis than is currently possible with behavioral testing alone. The field of research in neuroimaging and AD holds the potential for diagnosing not simply the behaviorally affected AD patient, but perhaps the patient who has yet to display cognitive manifestations of the disease. With several new lines of treatment under research, the most promising methodology for reducing the incidence of AD in the population is an earlier diagnosis, taking

advantage of future interventions that may slow disease progression. It is apparent that as imaging methods have become more sophisticated, they have detected brain changes occurring much earlier in life than previously assumed. By combining higher resolution structural and functional imaging methods, emphasizing change analysis, with genetic risk factors, there is promise in being able to identify brain changes as they first emerge and to identify a trajectory of change likely to lead to AD.

See also: Dementia: Alzheimer's.

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Neuromuscular System

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Glossary

Contractile Proteins – Actin (thin filament) and myosin (thick filament) interact to form the sliding filament mechanism of muscle contraction. The heavy chain isoforms are central in the regulation of muscle shortening speed.

Contraction – Muscle can contract with (dynamic) or without (isometric) movement. During movement, an active muscle can either shorten (concentric contraction) or lengthen (eccentric contraction).

Muscle Strength – The maximum force that can be produced by a muscle, which is specific to the type of contraction.

Plasticity – The ability of muscle to adapt to changes in usage. This can be at all levels, from changes in the expression of contractile proteins to its metabolism.

Power Output – The product of muscle force and speed of movement.

Sarcopenia – Age-related loss of muscle mass. The decline in muscle mass is closely associated with the decline in muscle strength in old age.

Introduction

Old age in both men and women is characterized by a reduction in muscle mass, which relates to a reduction in both the number and size of muscle fibers. This loss of contractile tissue is accompanied by a decline in muscle force production (strength) and power output. A loss of motor nerves in the spinal cord results in a reduction in the number of functioning motor units, while in those motor units remaining the number of muscle fibers is increased, as some of the fibers that have been lost become reinnervated. The proportion of fast myosin isoforms may be reduced in aged muscle as a consequence of a selective atrophy of the type II fibers, resulting in a slowing in the speed of muscle movement, amplifying the decrease in power-producing capability. With only small changes in body mass, functional ability and mobility are reduced as the muscle power to body mass ratio decreases. While the decline in physical performance seems an intrinsic part of the aging process, the aged neuromuscular system remains sensitive to improvements in muscle mass, strength, power, fatigue resistance, and coordination.

Properties of Skeletal Muscle

Contractile Properties

To understand the effects of the aging process on the neuromuscular system it is important to identify the factors that determine the mechanical properties of a muscle. The force–velocity relationship describes how, as a muscle contracts and actively shortens against an external load, the force that it can generate decreases in a hyperbolic manner with velocity of contraction. In contrast to traditional experiments undertaken by muscle physiologists on isolated muscle, in the body there are many factors that have an influence on contractile output; these include the activation of muscle and the role played by elastic structures in series with the muscle fibers, namely, tendons.

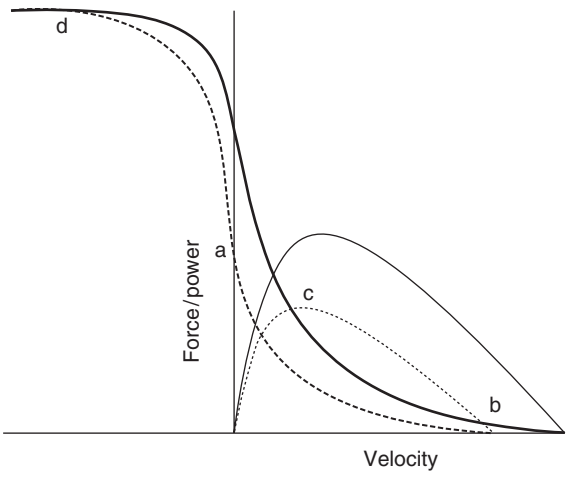

Figure 1 Schematic diagram showing the force–velocity and power–velocity relationships for a hypothetical young (continuous) and old (dashed) muscle. The older muscle may demonstrate lower isometric force (a), reduced maximum velocity of shortening (b), lower power output (c), but maintained function during stretch (d).

Strength, which can be defined as the amount of force that can be generated during a single maximal isometric (or static) contraction, is determined by the physiological cross-sectional area of a muscle, which is ultimately a reflection of the number of functioning subunits within muscle, the sarcomeres, working in parallel with one another. In contrast to isometric contractions, when a muscle is allowed to shorten, or contract concentrically, mechanical work is performed and the rate at which this work is performed is equivalent to power output. In other words, power is the product of force and velocity. As can be seen in **Figure 1**, power rises with increasing speed of movement until a velocity of shortening at approximately 30% of V_{max} is reached; here peak power is obtained. Power then declines with further increases in the speed of movement. As all movements of the body involve components of force generation and speed of movement, any changes in either of these variables will have an effect on the power that can be generated. Ultimately, it is the force-producing ability, the rate at which force can be produced and the power-generating capacity of the muscle, that will determine the ability of older people to perform a given physical tasks.

Contractile Proteins and Function

As mentioned previously, the isometric force that can be generated during a contraction relates most closely to muscle or fiber size, specifically to its cross-sectional area. This in turn is a reflection of the number of myosin cross-bridges, the molecular motors, that are

working in parallel. However, there is evidence to suggest that type II fibers are capable of generating ~20–30% higher force per unit area and thus have a higher specific tension. During movement, the implications for fibers expressing different myosin isoforms are marked. Fibers that contain MHC-I isoforms (type I, or slow fibers) are considerably slower, and as a consequence generate less power, than the two other types (MHC-IIA and MHC-IIX). Type I fibers are on average one-quarter to one-third slower than the other two types and also have a slower rate of force development. MHC-IIX isforms are the fastest to shorten and are capable of generating the highest power outputs.

Human skeletal muscles are not homogeneous; rather, each muscle comprises a mixture of fast- and slow- contracting fibers depending on the myosin isoforms, which are expressed and thus show differences in their contractile characteristics. This relates in large part to their functional roles. The calf muscle, for instance, is a postural muscle with the soleus muscle being dominated by slow-contracting, but fatigue-resistant, MHC-I fibers. For activities that require the generation of large power outputs, a large muscle with a higher proportion of fast myosins is obviously an advantage. Unfortunately, as we shall see later, the reverse situation exists in aging muscle, which is both smaller and slower.

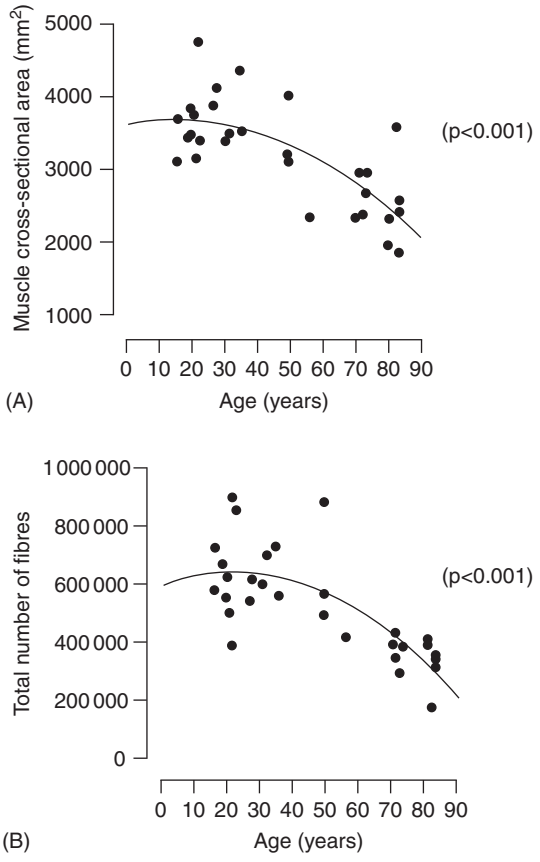

Figure 2 The relationship between age and (A) muscle cross-sectional area and (B) muscle fiber number. Reprinted with permission from Lexell J, Taylor C, Sjostrom m (1988) What is the cause of the ageing muscle? Total number, size and proportion of different fiber types studied in whole vastus laterals muscle from 15- to 83- year- old men. *Journal of the Neurological Sciences* 84: 275–294.

Properties of Aged Muscle

Muscle Mass and Force Production

As the force generated by a skeletal muscle relates most closely to its size, a large decrease in whole muscle cross-sectional area will have a dramatic effect on muscle force production. Muscle cross-sectional area can be estimated using various techniques, such as ultrasonography, computed tomography scanning, and magnetic resonance imaging, while whole body potassium and nitrogen and the 24-hour excretion of creatinine have been used as markers of whole body muscle mass. The numerous studies that have been performed in relation to increasing age clearly show that there is a marked decrease in muscle mass (sarcopenia) in aged muscle (**Figure 2A**). The similarity between the effects of disuse and those of aging on skeletal muscle has led to the suggestion that many age-related changes in muscle may relate to a disuse atrophy phenomenon, such as that seen in a leg that has been immobilized. Indeed, the extent to which the decline in muscle mass results from a preprogrammed loss of contractile tissue, or from a reduction in overall activity resulting in disuse atrophy, is one of the important questions still to be resolved in aged muscle. Studies that have analyzed whole sections of the vastus lateralis muscle indicate that the reduction in skeletal muscle size is due to both a loss of muscle fibers (**Figure 2B**) and a reduction in fiber size, particularly in the size of type II fibers. The latter factor, however, plays a relatively minor role. Associated with this decline in muscle mass is a decline in muscle strength. Data in this regard have primarily come from cross-sectional studies in which muscles from aged individuals have been compared with those of young and middle-aged adults. This method does have intrinsic limitations given differences in nutritional status and health care between generations. However, the findings of numerous studies are reasonably consistent. They show that a decrease in strength can occur in muscles of the upper and lower limb, in both distal and proximal locations, and that for both males and females the reduction in strength across the adult

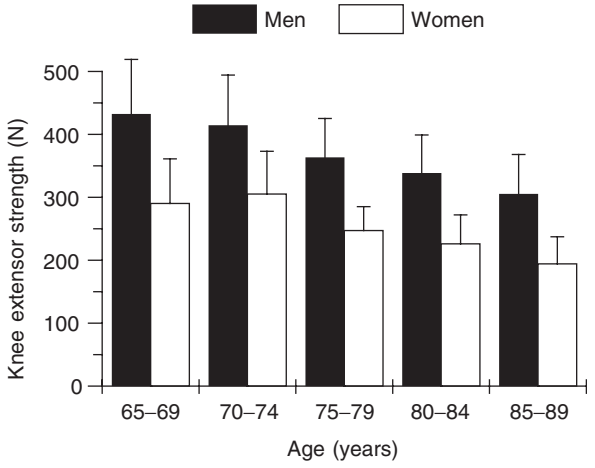

Figure 3 The effects of age on voluntary isometric knee extensor strength (±SE) in men and women ($n = 10$ in each age group). Data from Skelton DA, Young A, Greig CA, and Malbut ke (1995) Effects of resistance training on strength, power, and selected functional abilities of women aged 75 and older. *Journal of the American Geriatrics Society* 43: 1881–1887.

range tends toward being curvilinear, with the onset of the seventh decade being a turning point for an accelerated decline (see **Figure 3**). Between the ages of 30 and 80, deficits in muscle strength have generally been found to be in the region of 30% for the arm muscles and 40% for the leg and back muscles.

It has been suggested that the decline in force production in elderly muscle may relate, in part, to the ability of elderly subjects to activate fully the total muscle mass during a maximum voluntary contraction. However, even when the muscle is activated by direct electrical stimulation, aged muscle has been shown to be markedly weaker than that of young muscle. Indeed, the decline in force production has been shown to be greater than the decrease in muscle mass. This decrease in specific tension has partly been attributed to the increased content of fat and connective tissue in elderly muscle, resulting in overestimates of aged muscle cross-sectional area. However, there are reports that single muscle fibers obtained from human muscle biopsy samples and studied *in vitro* also produce less force per unit area than those from younger counterparts. In aged rodents, paramagnetic resonance studies of chemically activated fibers have revealed a lower proportion of myosin cross-bridges in the strong-binding high force (22%) compared with young fibers (32%). Furthermore, in aged rodents there is also evidence to suggest that the force loss is absent during stretching or eccentric contractions. There are similar observations in studies comparing young and elderly people, although the mechanisms underlying this phenomenon are as yet not clear.

Contractile Characteristics and Muscle Composition

The force–velocity properties of homogeneous muscles (comprising either virtually all type I or all type II fibers) of aged rodents have been reported to be essentially unchanged, but human muscles are far from homogeneous. As the shortening properties of skeletal muscle are closely regulated by the MHC isoforms they express, a reduction in the relative proportion of the fast myosin isoforms will have a reducing effect on the velocity at which the muscle will contract. A reduction in the ability of the muscle to shorten quickly, coupled with a decline in muscle force production, will have a marked effect on the power-producing ability of the muscle. Muscle fibers are traditionally determined on the basis of their ATPase histochemical staining properties. The question of whether there is a change in the distribution of histochemically determined fiber types with old age has been controversial. In studies in which whole muscle cross-sections of the vastus lateralis have been examined, it has been suggested that there is not a reduction in the proportion of slow, type I fibers, but a decrease in the area occupied by the fast, type II fibers. The histochemical technique, however, does not clearly show fibers that express more than one MHC isoform. Using single-fiber electrophoresis, elderly muscle has been shown to possess more of these 'hybrid' fibers. Furthermore, irrespective of a switch in myosin isoforms, the reduced volume of type II fibers means that there is a reduction in the relative amount of fast myosin in the muscles of elderly people.

Implications for Changes in Contractile Function

A decrease in force production in old age coupled with a slowing in shortening characteristics has a dramatic effect on muscle power production. Furthermore, the rate at which force can be developed is also slowed, relating in part to alterations in the Ca^{2+} release-repute kinetics from the sarcoplasmic reticulum. This results in impaired functional ability reflected in increased difficulty in performing everyday tasks such as rising from a chair or climbing stairs. As well as a decrease in power-generating capacity, a slowing of contraction results in a reduced capacity for the rapid production of force in protective reflexes, thus amplifying the impact of muscle weakness on mobility and increasing the risk of falls. Importantly, these changes are worse for an elderly person than they would be for a young person losing an equivalent amount of strength. This is because despite the loss of muscle mass, the older person's whole body mass remains relatively unchanged as fat

mass increases. This has implications for power output during physical tasks. A weaker muscle contracting against a similar load, whether it be an unchanged body mass or a 20 kg bag of potatoes, must use a greater proportion of its maximum force-generating ability. The force–velocity relationship of muscle dictates that this must be at a slower speed. Thus, for high force contractions, this slower speed of movement means less power.

Changes in the Nervous System and Motor Unit Properties

A key question regarding the loss of muscle mass with increasing age is whether this is a change intrinsic to the muscles themselves, of neural origin, or a combination of both. It is known that there are a reduced number of alpha motor neurons in the spinal cord of elderly people and that nerve conduction velocity decreases, with the peripheral segment reflex loop being significantly delayed in aged individuals. Furthermore, impaired neuromuscular transmission and reduced muscle membrane excitability seem to be further consequences of old age. Electrophysiological evidence also suggests that there is a loss of functioning motor units, but with an increase in the size of those motor units remaining, that is, each remaining motor unit contains more muscle fibers. This phenomenon has implications for fine control of movements and coordination.

There is experimental evidence that in this reinnervation process there is a preference for a specific fiber to be reinnervated by its own type of motor nerve. Type grouping is found in muscles of elderly humans ($> \sim 75$ years), which is probably a sign of a less effective reinnervation procedure. Of note is the extent to which these neurological phenomena vary between muscles, with the anatomically more distal regions seemingly most affected.

Skeletal Muscle Metabolism

With a weaker muscle, the relative forces and power outputs required to perform tasks that require given absolute loads (such as body weight) are higher. Thus, in one sense the older muscle might appear to be more fatigable. In addition, age-related mutations in mitochondrial DNA might suggest a cause for reduced endurance of the aged muscle. However, there is little evidence to suggest that the intrinsic fatigue resistance of the aged muscle is lower than that of a young muscle. Muscle fatigue is determined by a number of physiological and metabolic phenomena relating to the type and intensity of exercise. The activation of fatigued muscle, as indicated by neuromuscular transmission, does not seem to be the limiting factor in old age, although there is some evidence of a decrease in the amount of Na^+-K^+ pumps in elderly muscle, which might reduce the clearance of K^+ during exercise-induced hyperkalemia.

Oxygen availability to individual muscle fibers is determined, in part, by the degree of capillarization. Similar capillary densities are observed in elderly men and women as compared with younger people (**Table 1**). During low-intensity exercise, ATP production occurs from the aerobic metabolism of glycogen and fat. Thus, despite reports of mutations in mitochondrial DNA, measurements of the enzymes responsible for the aerobic breakdown of glycogen in the Krebs cycle (e.g., citrate synthase, succinate dehydrogenase) and of fat through beta oxidation (e.g., 3-hydrox Co-A dehydrogenase) have been shown to be unchanged, or in some instances only slightly reduced, in old age (**Table 1**). Enzymatic capacity is inextricably linked to activity pattern, making interpretation of the effects of aging per se difficult; however, studies examining the muscles of activity pattern, or training status, in matched older and young individuals suggest no effect of the aging process. In contrast to low-intensity exercise, the demand for ATP is greatly accelerated during high-intensity exercise, such that its supply by aerobic metabolism cannot be maintained. During high-intensity exercise ATP is generated initially from the breakdown of phosphocreatine (PCr) and from anaerobic glycolysis. The enzymes regulating PCr

Table 1 Capillary density and oxidative enzyme capacity in muscle

	Young			*Elderly*			
				Sedentary			
	Sedentary	*Joggers*	*Athletes*	*(> 60 yr)*	*(> 80 yr)*	*Joggers (> 60 yr)*	*Athletes (> 70 yr)*
Capillaries (cap. fiber^{-1})	1.2	1.6	2.7	1.4	1.5	1.7	2.5
Citrate synthase (μmol g^{-1}min^{-1})	31	42	82	34	39	34	61
3-Hydroxyacl-CoA-dehydrogease (μmol g^{-1}min^{-1})	27	36	76	29	32	32	58

breakdown (creatine kinase) and glycolysis (phosphorylase, hexokinase, lactate dehydrogenase, phosphofructokinase) do not appear to be adversely affected by aging in sedentary humans. Moreover, the availability of the high-energy substrates (ATP, PCr) is similarly not affected.

What Causes the Change in Aging Muscle?

The mechanisms underlying changes in skeletal muscle are unclear. Whether the aging process represents a cell- and organ-specific response to genetic preprogramming, or whether other factors relating to a decrease in usage, either coupled to a general reduction in physical activity or to a reduction imposed by other factors not directly related to the neuromuscular system, is not known. For example, changes in the amount of or sensitivity to different circulating hormones may be responsible for some of the alterations observed in aged muscle. It has been suggested that the decrease in muscle mass and thus force-generating capacity may be at least partly related to changes in the amount of anabolic hormones such as growth hormone (GH), insulin-like growth factor-I (IGF-I), and testosterone. In women, a significant decline in muscle force production has been shown to correspond to the time of onset of menopause, when estrogen levels are falling, independent of a loss of muscle mass. This specific strength loss can be offset by hormone replacement therapy. The thyroid hormones may also be of importance, as in rats they have been shown to have a marked influence on the expression of myosin isoforms and on contractile characteristics. However, the extent to which the effects of aging per se and the effects of various experimental interventions reported in animals can be extrapolated to humans remains unclear.

Under the microscope, aged skeletal muscle exhibits features of both neuropathy and myopathy with a predominance of neuropathic alterations. These neuropathic alterations include the presence of small angulated fibers and increased fiber type grouping. Myopathic-like changes include dilation and proliferation of the sarcoplasmic reticulum–transverse tubular (SR-T) system, myofilament disorders, streaming of the Z band and rod formation, accumulation of lipofuscin and lipid droplets, infoldings of the sarcolemma, aggregation of muscle nuclei, and alterations in the amount and structure of mitochondria.

Several hypotheses have been proposed for the deterioration of muscle and muscle function. These include the theory that as a result of random damage (wear and tear) or due to damage from free radicals, errors occurring in the duplication of DNA increase, so that when a significant number of errors accumulate, abnormal mRNA and protein molecules are formed that do not function normally. Free radicals are produced from the oxidation of free fatty acids. These oxygen molecules that bear free electrons are highly reactive and can easily tie up and weaken proteins and cause damage to DNA. This theory has particular relevance for skeletal muscle, given the large aerobic energy metabolism in exercising muscle. Another theory suggests that there is an inherent biological clock: just as some genes control embryonic development, so other genes program the aging processes. The changes associated with old age may thus result from the normal expression of a genetic program that begins at conception and ends in death.

Adaptability of Aged Muscle to Physical Activity

As mentioned previously, an unresolved question is whether the alterations observed in the muscles of elderly people are solely a function of age or whether usage of muscle when growing old also plays a role. Human skeletal muscle is very plastic, and disuse and usage are critical determinants of both the size of a muscle fiber as well as its qualitative characteristics, such as the isoform pattern of contractile proteins, energy-related enzymes, and membrane-bound regulatory proteins. This plasticity appears to be present not only in muscles of the young, but also in elderly people.

Increasing Muscle Size and Strength

Both cross-sectional and longitudinal studies have shown the efficacy of high-resistance strength training in improving muscle mass and function in older people. In 70-year-old men who have been physically active through strength (high-resistance) training, muscle force and muscle cross-sectional area are comparable to those of sedentary young adults. Muscle cross-sectional areas of both arms and legs can also be maintained in these elderly people. This is accomplished by a larger mean fiber size to compensate for a reduced number of muscle fibers. Studies of elite master weightlifters show that they have superior strength and power output when compared with non-trained, healthy, age-matched individuals. However, the age-related rate of decline is actually similar for both (**Figure 4**).

In recent years, several well-controlled longitudinal studies have been performed to evaluate the effect of increased usage through strength training by elderly people. The general finding is that, as with young adults, task-specific muscle function can be

vastly improved in just a few months by regular training (**Figure 5**). At the same time, the changes in maximum isometric strength and muscle cross-sectional area as a result of training are, as is the case with young people, not as impressive. This suggests that the elevation in, for example, 1RM (one repetition maximum) is primarily a function of improved neural drive. The positive effects of strength straining appear to be similar even in those subjects considered to be the oldest-old (>85 years). A critical factor for obtaining these marked improvements is that the training is characterized by a regime of high-resistance loading with few repetitions. Thus, the total time for training may amount to only 10 min per day. It appears favorable to use training loads exceeding 70% of 1RM. Such high muscle force developments can be sustained by elderly people. This has been shown repeatedly, not only in small studies with small numbers of selected elderly subjects, but also in population-based samples (**Figure 6**).

The mechanisms by which muscle mass is increased in response to strength training are becoming better understood. For a muscle to get larger there must be a net gain in protein, by an increased rate of synthesis, a reduction in degradation, or both. The older muscle has a slower rate of muscle protein turnover as determined by studies in which labeled amino acids are infused and their rate of incorporation into muscle

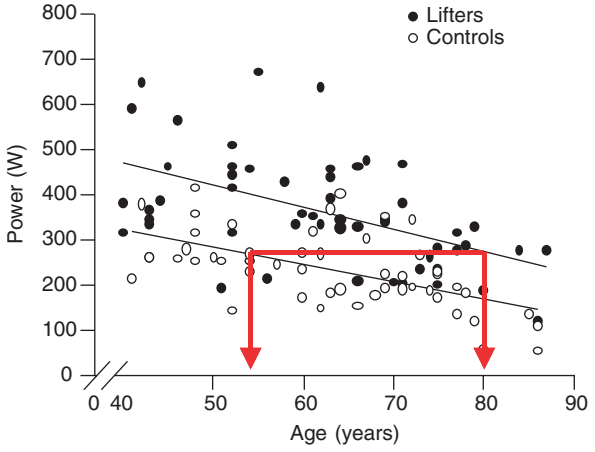

Figure 4 Power output from the lower limb extensor muscles in master weightlifters and non-active but healthy control subjects. The data show that on average the weightlifters were 35% more powerful, and that both groups had a similar 1.6% per annum decline. The red arrows indicate that power output from an 85-year-old weightlifter is equivalent to that of a non-active subject 25 years younger. Adapted from Pearson *et al.* (2002) Muscle function in elite master weightlifters. *Medicine and Science in Sports and Exercise* 34: 1199–1206.

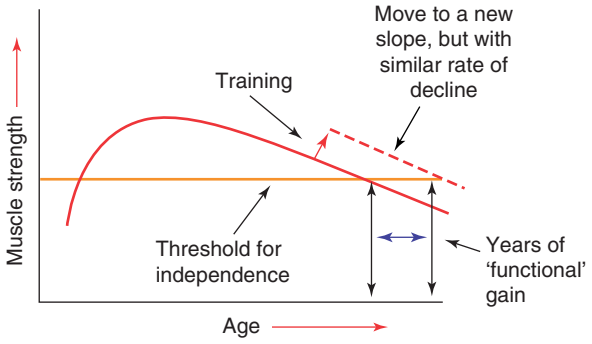

Figure 6 A hypothetical diagram showing the change in muscle strength with increasing age and the potential for improving function through strength training.

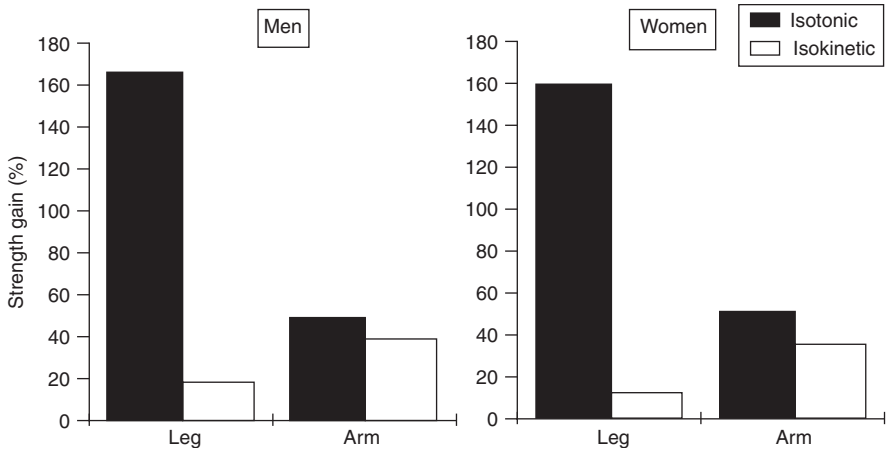

Figure 5 The effects of high-load (free weights) resistance training on the isotonic and isokinetic (constant speed at $30^{\circ}\,s^{-1}$) strength of the knee extensors and elbow flexors in elderly men and women aged 70–77 years. Note the similarity in responses between men and women, the greater improvement in isotonic, compared with isokinetic strength and the greater improvement in the leg compared to the arm muscles, despite similar training loads (three sets of six repetitions at 85% 1RM, three times per week for 11 weeks). Data from Lexell J, Dowham DY, Larsson Y, Bruhn E and Morsing B (1995) Heavy-resistance training for Scandinavian men and women over 70: short and long-term effects on arm and leg muscles. *Scandinavian Journal of Medicine and Science in Sports* 5: 329–341.

measured. However, older muscles seem as responsive to increasing rates of protein synthesis as young muscles when undertaking high-resistance exercise. The intracellular events that initiate increased protein synthesis are also becoming understood and relate to the upregulation of local growth factors in muscle such as IGF-I, which have autocrine and paracrine actions. These stimulate increases in protein synthesis by activating intracellular signaling events to initiate and facilitate translation and by activating the satellite cells. These are the muscle stem cells, which when activated by overload can either differentiate into myoblasts and ultimately form functioning contractile proteins, or remain in the mononucleate state and function as new nuclei to manage the enlarged muscles fibers. Older people have been shown to upregulate IGF-I and its splice variants (IGF-IEa and mechano growth factor, MGF) as a result of high-resistance exercise training, although there is some evidence to suggest that they may be less able to do so than younger people. Older people are also able to increase satellite cell number in response to strength training. In healthy elderly subjects, nutritional supplementation per se does not add to the improvement in strength, but the appropriate timing of protein intake shortly after exercise may help to facilitate the adaptation process.

Muscle Fiber Number

The role of physical activity in retarding the rate by which muscle fibers are lost with age is not clear. Indirect estimates based on measurements of cross-sectional area of the muscle and mean muscle fiber size suggest that active muscles of elderly people may contain more fibers ($\sim$15%). No thorough evaluation has been performed to estimate muscle fiber number with brief periods of training in elderly subjects. With small and similar changes observed in mean muscle fiber area and whole muscle cross-sectional area, it is unlikely that the training has an effect on the number of muscle fibers. It may, however, if the training period is extended. With daily strenuous muscle usage, muscle fiber number has been shown to be maintained at a 30% higher level in active compared to inactive rats. Thus, slowing the rate by which muscle fibers are lost may be a significant factor in maintaining muscle mass in the elderly. It needs to be demonstrated whether the less marked loss of muscle fibers observed with muscle usage is due to the death of fewer spinal motor neurons or to an increased reinnervation activity of the remaining functional peripheral motor nerves.

Muscle Fiber Types

Lifelong physical activity may affect muscle fiber type composition. Strength-trained elderly men have been shown to have the highest percentage of type II fibers, in both leg and arm muscles. In contrast, elderly joggers have the highest percentage of slow fibers in the leg muscles. Similar observations are available on elite master athletes who had been runners all their lives. Notably, however, muscles that have been dynamically active for a lifetime may have 20–30% more slow-twitch fibers. More specific methods to characterize the isoform pattern of the contractile proteins such as immunocytochemistry and single-fiber electrophoresis give a similar pattern of change as the one described previously.

Differences in muscle fiber composition comparing young and older sedentary people tend to be more marked in the leg than in the arm muscles. Whether this is due to differences in muscle usage is not known. In a small number of very active elderly runners studied, the coexpression of MHC isoforms in the leg muscles was found to be similar to that found in young subjects, while strength training also reduces the degree of coexpression. It is a possibility than an exercise stimulus aids in more proper regulation of gene transcription in the elderly.

No change in muscle fiber types has been observed in longitudinal studies as a result of training, but that does not exclude the possibility that changes could occur, provided that the duration of the training is longer (many months), and techniques more sensitive than traditional histochemistry are used to identify the MHC isoforms.

Capillaries and Mitochondrial Enzymes

Muscles of endurance-trained elderly men contain a very high number of capillaries, and their mitochondrial enzyme activity levels are high (**Table 1**). Indeed, these men are at a level similar to young endurance athletes. Less regular and strenuous endurance activities are also effective, although the absolute level of adaptation is smaller than that in top-trained athletes, but nevertheless is above that observed in young sedentary men.

Oxygen delivery to muscle during exercise is reduced in elderly subjects due to a drop in maximal heart rate and stroke volume. This also occurs even in very active elderly subjects, as the reduction in maximal heart rate is unaffected by the level of physical activity. With a maintained capacity of the muscle to receive a given blood flow and to utilize oxygen, there is a relative overcapacity for aerobic metabolism in the muscle of the elderly. The functional significance is a more favorable muscle metabolism during exercise, as indicated by a low blood lactate accumulation and a low respiratory exchange ratio, that is, a large lipid oxidation, even at quite high exercise intensities.

Little is known about the effect of short-term training on aged muscles in humans, as it has not been a focus of many studies. As the successful training programs for improving strength incorporate few repetitions and each session is of short duration, it is highly unlikely that muscle capillaries or mitochondrial enzymes would be enhanced. Rather, if there is fiber enlargement, a dilution effect may occur, with less capillaries and mitochondria present per unit area or volume.

In endurance training studies on rodents, there is an increase in both the number of capillaries and mitochondrial capacity, clearly demonstrating that aged skeletal muscle maintains its capacity to adapt to demands in regard to aerobic metabolism.

Membrane-Bound Regulatory Proteins

Na^+-K^+ pumps and Ca^{2+}-ATPase of the SR system are affected by physical activity, and as for other muscle characteristics, the effect is specific to the type of muscle usage. High-resistance activities over a lifetime maintain the Na^+-K^+ pump better than endurance activities, whereas the reverse is true for Ca^{2+}-ATPase. These maintained capacities are likely to have a functional role by retarding the rate at which fatigue develops during high-intensity and endurance exercise.

In rodents, a training-specific effect is observed for both Na^+-K^+ pumps and Ca^{2+}-ATPase of the SR system, confirming the finding in cross-sectional studies. Resistance training is needed to affect the [^{3}H]ouabain binding sites, and repetitive monotonous activation affects the Ca^{2+}-ATPase. Studies have also shown that the age-related slowing in the rate of Ca^{2+} reuptake by the sarcoplasmic reticulum can be reduced in older people by strength training.

Conclusion

The progressive decline in muscle force (strength) is primarily related to a loss of muscle mass (sarcopenia). The loss of muscle power is even greater, as the effects of a loss of muscle mass are exacerbated by a relatively greater loss of the fast (type II) myosins. From an anatomical perspective, the loss of muscle mass is caused by a reduction in muscle fiber and motor unit number. However, skeletal muscle retains the ability to adapt to overload, even in very old age. But the evidence from older individuals who have maintained very high levels of physical activity suggests that there are age-related changes in muscle, which are independent of changes that may occur as a result of lower levels of physical activity in later life. In other words, the capacity of muscle to improve its function is retained. This will improve function, but not ultimately prevent an age-related decline. Nevertheless, what this means in absolute terms is the 'buying back of years.' Although master weightlifters appear to have a rate of decline in muscle power similar to non-active individuals, in absolute terms they are far superior, such that their lower limb extensor power-generating ability is equivalent to non-active individuals some 25 years younger then themselves (see **Figures 5 and 6**).

Other qualities of skeletal muscle, such as capillaries, substrate availability, and energy-related enzymes, in elderly people are kept at levels comparable to young adults, and the response to training is similar to that observed in young people. As with young people, there is a very high degree of specificity in the response to training. High-load strength training affects mainly muscle fiber size and fiber number as well as ion pumps, whereas endurance training primarily affects capillary proliferation, mitochondria, oxidative enzyme activity, and the Ca^{2+}-ATPase of the SR system.

Finally, it is clear that some of the alterations that are observed in the muscles of healthy elderly people relate to a lack of muscle usage. The good news is that muscle remains sensitive to increased activity even in very late life.

See also: Endocrine Function and Dysfunction; Falls; Metabolism: Carbohydrate, Lipid and Protein; Motor Control; Touch and Proprioception.

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Neurotransmitters and Neurotrophic Factors

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Glossary

Age-Related Neurodegenerative Diseases – Diseases in which age is a primary risk factor and that are characterized by atrophy or death of nerve cells; examples are Alzheimer's disease and Parkinson's disease.

Neurotransmitters – Chemicals mediating the transfer of information between nerve cells at synaptic junctions.

Neurotrophic Factors – Proteins regulating survival and morphological plasticity of nerve cells.

Introduction

Neurotransmitter release and the receptor mechanisms stimulated by them are key determinants of brain function and ultimately serve to modulate a variety of complex body functions such as movement, learning, memory, mood, and sensory processing. By comparison, neurotrophic factors are proteins that regulate the survival of nerve cells and are required for normal development and maintenance of structural integrity of the nervous system. The function of neurotransmitters and neurotrophic factors changes during aging. However, such changes are selective, and there is no evidence of global decline. Neurotransmitters and neurotrophic factors are also affected by neurodegenerative disease and play a central role in the pathophysiology of the disease process. Current therapies and approaches to future therapy of such diseases are based on influencing neurotransmitter and neurotrophic factor mechanisms.

Role of Neurotransmitters in Brain Function

Nerve cells are the functional units of the nervous system and form physical contacts with one another to facilitate intercellular communication throughout the brain and spinal cord. The concept that neurons are independent units and can form close functional contacts to permit the transfer of information from one cell to another is called the neuron theory of brain function. This theory was first proposed by the Spanish neuroanatomist Santiago Ramon y Cajal at the end of the nineteenth century and has formed the basis of understanding how the brain functions for over 200 years. The chemical signal that transfers information from one neuron to another is called the neurotransmitter, and in the early 1900s Sir Charles Sherrington, the English Nobel Laureate, coined the term synapse to describe the site at which two neurons come into contact.

Synapses in which neurotransmitters communicate information from one cell to another are called chemical synapses. Presynaptic information is carried by the axon as an electrical impulse from the cell body to the axon terminal of the presynaptic cell, where it is converted into a chemical signal. This chemical signal, or neurotransmitter, is released in small quanta from membrane-bound vesicles (synaptic vesicles) and crosses a physical gap (about 20 nm) between the pre- and postsynaptic neurons, called the synaptic cleft (**Figure 1**). Transport of the neurotransmitter across the synaptic cleft is carried out by simple diffusion and does not require the use of an energy-dependent mechanism. Upon arrival at the postsynaptic cell, the neurotransmitter combines with a protein receptor embedded in the cell membrane that is specifically designed to bind with the neurotransmitter. Binding of the neurotransmitter to the receptor initiates a series of postsynaptic cellular events that ultimately serve to modulate a variety of complex body functions such as movement, learning, memory, mood, and sensory processing. Local postsynaptic effects last as long as the neurotransmitter remains bound to the receptor. Neurotransmitters are eventually deactivated by a degrading enzyme or transporter protein that takes the neurotransmitter back into the presynaptic nerve terminal. In this way, transmission of information between nerve cells is unidirectional and does not involve the direct transfer of the electrical signal from one cell to another.

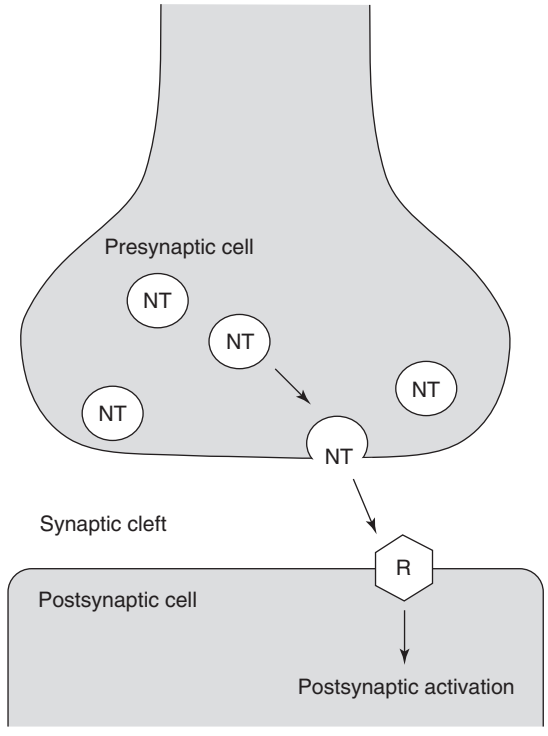

Figure 1 Schematic drawing of chemical synapse. Neurotransmitter (NT) is released in small quanta from synaptic vesicles at the presynaptic terminal. The neurotransmitter diffuses across the synaptic cleft and binds to the receptor (R) in the postsynaptic membrane.

A molecule is considered a 'classical' neurotransmitter if it meets several criteria. First, the molecule must be synthesized and released by the presynaptic neuron. Second, it reproduces the same effects in the postsynaptic cell as when the presynaptic neuron is independently stimulated. Third, postsynaptic effects of the molecule can be blocked by competitive antagonists, and fourth, there is an appropriate mechanism to inactivate the molecule in the synaptic cleft. Although more than 100 small peptides have been shown to be biologically active in both the central and peripheral nervous systems at the level of the synapse and can alter the electrophysiological state of the postsynaptic cell, few have passed the rigorous criteria for being considered a classical neurotransmitter. These include the biogenic amines (dopamine, norepinephrine, epinephrine, serotonin, histamine), acetylcholine, γ-aminobutyric acid (GABA), glycine, and glutamate.

Individual neurons contain only one type of neurotransmitter, but these neurotransmitter-specific cells are distributed across various regions of the brain and spinal cord. Like dopamine neurons of the substantia nigra (SN), they can be clustered in specific ganglia or nuclei, or, like glutamate neurons, can be spread out ubiquitously across the nervous system, serving as a component of multiple neuroanatomical pathways. In addition, based on previous clinical, neuropathological, and experimental studies, it is clear that certain biological functions can be linked to specific neuroanatomical pathways that use a particular neurotransmitter to communicate information between neurons. Examples of this functional/biochemical correlation include the dopaminergic neurons of the SN in the regulation and coordination of movement and cholinergic neurons of the basal forebrain in learning and memory. The obvious corollary to this anatomical organization is that damage to a neurotransmitter-specific neuroanatomical pathway as part of aging or disease can underlie primary characteristics of the disease. This is most readily seen in Parkinson's disease, in which loss of dopamine neurons is directly involved in symptomatic movement problems, and Alzheimer's disease, in which cognitive impairment is linked with loss of acetylcholine activity. However, it is apparent from the neuropathological literature that neurodegenerative diseases of the central nervous system (CNS) are not the result of the loss of a single neurotransmitter system but are composites of global neurotransmitter deficits and other neuropathologies that

result in the generation of the range of behavioral characteristics typical of a particular disease state (*see* Brain and Central Nervous System).

Role of Neurotrophic Factors in the Nervous System

Neurotrophic factors are proteins that regulate the survival and developmental growth of nerve cells. Although the adult brain does not undergo the same degree of morphological change as it does during development, most adult neurons retain the ability to modify their morphology as a way to adapt to changes in their surrounding environment. This adaptive process, generally referred to as neural plasticity, is essential to the formation and maintenance of the wide network of limbic, striatal, and cortical circuits that regulate the complex array of human behaviors. Like neurotransmitters, neurotrophic factors act as chemical signals between cells and can effect short-term changes in synaptic activity as well as long-lasting changes in neuron morphology and neuron survival. However, neurotrophins are not directly involved in the propagation of signals along neural pathways in the manner that neurotransmitters are. Neuronal trophic support does not follow the unidirectional flow that neurotransmission does, but rather is derived from both antero- and retrograde sources, from other neurons as well as glia and other cell types (**Figure 2**).

Known neurotrophic factors include the neurotrophin family, consisting of nerve growth factor (NGF), brain-derived neurotrophic factor (BDNF), neurotrophin-3, and neurotrophin-4/5. Other factors that function as neurotrophic factors are ciliary neurotrophic factor and the family of glial cell-derived neurotrophic factor (GDNF) proteins, which include GDNF, neurturin, artemin, and persephsin. In addition, there are proteins with neurotrophic factor functions among the members of the fibroblast growth factor family, epidermal growth factor family, transforming growth factor (TGB-β) family, and insulin-like growth factors (IGFs). Growth factors act by stimulating specific receptor molecules embedded in the cell membrane and provide trophic support for responsive cells.

A biological role for the neurotrophins is particularly well established in the development of the peripheral nervous system. There, neurotrophins play an essential role in regulating the fate of precursor neurons of the neural crest and in the development of sensory neurons of the dorsal root ganglia. In the CNS, neurotrophins provide trophic support for the survival of neurons during embryonic development and can elicit short- and long-term adaptive changes in synaptic efficacy and neuronal morphology in the adult. It is believed that the maintenance of high levels of neurotrophins and their receptors in specific regions of the adult brain, such as the cortex and hippocampus, corresponds to areas that demonstrate a high level of neuroplasticity associated with learning, memory, and motor learning. Likewise, evidence suggests that when the adult brain is damaged by trauma or disease, these developmentally regulated neurotrophic mechanisms are brought back into play and form the basis for compensatory repair mechanisms critical for determining the limits of functional recovery that can be expected after brain injury.

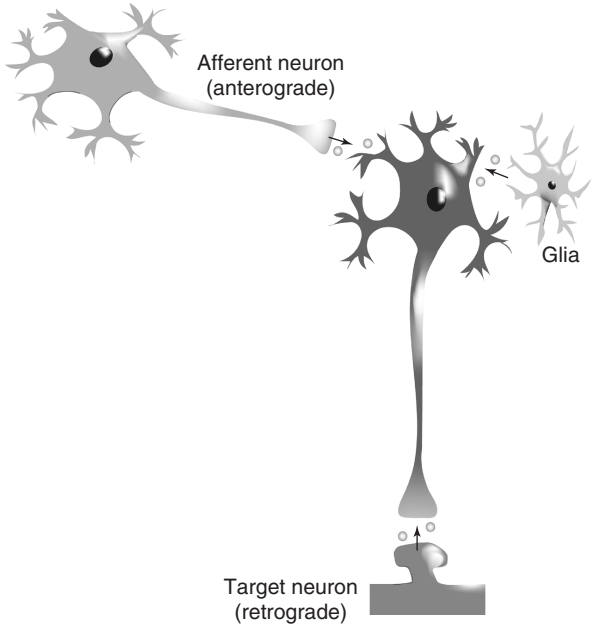

Figure 2 Possible sources of neurotrophic support. Neurotrophic support does not follow the traditional unidirectional flow that neurotransmission does, but rather is derived from both anterograde and retrograde sources as well as from adjacent glia. Sources include afferent neurons that synapse with other CNS and PNS neurons (anterograde), target neurons or tissues in other parts of the CNS or PNS (retrograde), and glial cells such as astrocytes adjacent to CNS neurons that produce growth factors.

Neurotransmitters and Neurotrophic Factors in the Aged Brain

Two of the most prominent principles that underscore gerontologic research in general and neurotransmitter and neurotrophic factor studies in particular are the following: (1) organisms age at different rates, as do different biological systems in their bodies, and (2) identifiable differences can be demonstrated between biological and chronological age among individuals of like age. The divergence between biological and chronological old age is most

obvious in the human population but is not limited to the human experience. Functional variability with age is a consistent feature across species and is closely tied to the variability in neurotransmitter and neurotrophin changes found in different regions of the nervous system. In addition, research conducted during the 1980s has forced us to reevaluate the traditional view that age-related changes in brain function can be represented by simple cell loss. Rather, it is now widely accepted that the aging nervous system functions as a composite of various adaptive responses in neurotransmitter and neurotrophin neurons that together preserve and repair the nervous system's neural networks against a background of progressive age-related cell dysfunction. In addition, it is well established that screening animals of like age for common behavioral characteristics and correlating behavioral changes with the anatomical and biochemical changes in specific neurotransmitter and neurotrophin systems is an extremely useful approach for studying mechanisms of 'usual aging,' abnormal aging, and disease.

The degree to which age-related changes occur in neurotransmitter systems that form the anatomical neural circuitry of the brain and spinal cord is variable at best. Studies that have reported on age-related morphological changes in neurons suggest that advancing age has a differential effect on cell loss and the biochemical content in different populations of neurotransmitter neurons in the same region of the brain. For example, it has been reported that aging in the SN of rodents is associated with a decline in the number of GABAergic neurons in the pars reticulata, but not dopaminergic neurons of the adjacent pars compacta. In addition, evidence suggests that the degree to which cell loss occurs in the same region of the brain for a particular population of neurotransmitter neurons varies in rodent, non-human primate, and postmortem human brain. For example, the lack of dopaminergic cell loss in the rat pars compacta of the SN is consistent with previous biochemical studies that reported small and inconsistent losses of dopamine and tyrosine hydroxylase activity in the nigrostriatal system of aged mice and rats. Similarly, anatomical studies in squirrel monkey have reported no difference in total cell number of dopaminergic neurons of the substantia nigra between young, middle-aged, and old experimental groups. In contrast, comparison studies in young and aged rhesus monkeys found a significant age-related decrease in nigral neurons accompanied by a substantial impairment in motor function. In postmortem human brain anatomical studies, dopamine cell loss is generally comparable to that found in the rhesus monkey. Specifically, cell loss ranges from 7 to 10% per decade up to 90 years of age; however, cell loss is not always accompanied by significant cognitive and motor deficits. Although the reason for the dissociation between the degree of cell loss and the onset of clinical symptoms is unclear, it has been suggested that while some dopamine neurons show signs of age-related atrophy or cell death, neighboring neurons may increase their rate of synthesis in order to compensate for this metabolic decline. This compensatory process, hypothesized to maintain the content within the normal range despite the metabolic decline in some cells, is similar to what has been reported in experimental studies of rats following acute neurotoxic lesions of the SN using the dopamine neurotoxin 6-hydroxydopamine (6-OHDA). Following an injection of 6-OHDA, some dopamine neurons of the SN show continual signs of neurotoxicity, atrophy, and cellular degeneration, while others increase their rate of dopamine synthesis to offset the death of neighboring cells. It may be suggested that a similar compensatory phenomenon occurs in normal aging and that individual neurons within the SN may be differentially sensitive to the effects of the aging process. However, the time over which these adaptive responses can compensate for age-related cell dysfunction is limited. Recent studies of this compensatory response in aging rats found that in the oldest animals, the capacity to increase dopamine turnover is lost. Similarly, following unilateral damage to the dopamine system in monkeys following intracarotid administration of the neurotoxin MPTP, increased turnover is maintained through middle age but is completely absent in older animals. These studies suggest that while the compensatory mechanisms designed to adapt to age-related neuronal damage are active during youth and middle age, they substantially decline in old age. Studies to determine whether lifestyle changes such as alterations in diet and exercise can push back the time when these compensatory mechanisms are no longer effective are only just beginning, but have shown promise. In particular, evidence suggests that an active lifestyle including structured programs involving mental and physical exercise can enhance personal well-being, increase cognitive function, improve cardiovascular health, and reduce the risk for developing dementia in old age. In addition, it is believed that the specific signaling pathways in the brain thought to be important determinants for maintaining a healthy brain include the neurotrophins BDNF and IGF and the neurotransmitters dopamine, norepinephrine, and serotonin.

The degree to which neurons that contain the same neurotransmitter are affected by age in different regions of the nervous system is also variable. For

example, studies have consistently reported a loss of cholinergic interneurons and activity of choline acetyltransferase, the rate-limiting enzyme for the synthesis of acetylcholine, in the striata of aged mice, rats, and humans. This may suggest that cholinergic neurons may be particularly vulnerable to the aging process. However, age-related cholinergic cell loss is not a general characteristic for cholinergic neurons of the basal forebrain, a region of the brain particularly involved in learning and memory. Most revealing, however, is the demonstration of the close association between functional and biochemical changes that occur in neurotransmitter neurons regardless of the age group examined. Previous studies used a variety of behavioral tests to divide rats of like age into behaviorally impaired and unimpaired age groups and have correlated cell number and biochemical content for a number of neurotransmitter systems with functional performance. Among the most robust relationships revealed by this approach is the correlation between changes in performance on spatial learning and memory tasks (e.g., Morris water maze, radial arm maze) and age-related changes in the hippocampus, in particular with age-related degenerative changes in cholinergic neurons. In addition, age-related impairments in learning and memory on inhibitory avoidance tasks have been correlated with the loss of norepinephrine from the locus coeruleus. Deficits in motor performance, as assessed by performance on a rod balance task, have been linked with an age-related increase in the number of atrophic GABAergic neurons in the striatum. Consistent with this evidence is the premise that the variability in functional performance increases with age and that deficits in specific behavioral parameters may or may not be correlated with alterations in selective neuroanatomical pathways in the brain. In addition, evidence suggests that age-related behavioral deficits, such as changes in cognition and motor function, are species specific. Thus, when data from neurogerontological studies are analyzed with age as the only independent variable, the ratio of functionally impaired versus unimpaired animals that constitute a specific sample population may directly confound the outcome of the experiment in terms of the relationship between age, behavioral performance, and neurobiological substrates. Furthermore, neurobiological changes that occur profoundly in some aged animals can be masked by the variability across old animal populations and can be parceled out only by relating neurobiological measures to behavioral performance.

The situation is further complicated by possible changes at the level of neurotransmitter receptors in the aged brain without significant cell loss or decreases in neurotransmitter content. Previous studies have found that the loss of neurotransmitter receptors is one of the more common characteristics of normal aging and is often correlated with age-associated changes in learning and memory, motivation, and motor function. Age-related changes in neurotransmitter function attributed to alterations in postsynaptic receptors have been described in varying degree in multiple neurotransmitter systems, including glutamate, dopamine, norepinephrine, GABA, and acetylcholine. A decrease in the NMDA glutamate receptor is one of the most consistent findings of neurogerontologic research, occurring across a variety of brain regions in species ranging from rodents to non-human primates. The magnitude of the decrease is routinely reported as between 20 and 50% and has been strongly correlated with hippocampal memory deficits in rats and monkeys. Likewise, decreases in the D1 and D2 dopamine receptors have been described in the striatum of rodents, non-human primates, and humans. In addition, in humans, an age-dependent decline in dopamine receptor activity has been confirmed in the cortex, striatum, and thalamus using non-invasive nuclear medicine techniques such as positron emission tomography (PET) and single photon emission computed tomography (SPECT). However, decreases in dopamine receptors do not always correlate with a functional decline across species. While loss of D1 receptors in the frontal cortex has been associated with age-associated cognitive deficits in executive function in humans, decreases in cognitive function mediated by the frontal lobe are not linked to loss of D1 receptors in aged rhesus monkeys. The variability between structural and functional change in aged animals again points to the necessity to screen aged animals so that behaviorally impaired animals are evaluated as a separate group from those that are not behaviorally impaired so as not to introduce unwanted confounds to the data analysis.

Much of the work regarding neurotrophins and aging has examined trophic effects at the cellular level. Evidence to support the hypothesis that mechanisms related to neurotrophic factors are involved in senescence is still emerging. Previous studies showed that the decline in the proliferative capacity of certain cells in culture seems to be associated with alterations in their response to growth factors. For example, the expression and functional response of receptors mediating the biological actions of epidermal growth factor (EGF) decline during the proliferative senescence of endothelial cells in culture. In addition, the effects of aging on trophic activity derived from striatum and relevant to the dopamine system have been studied in aging rats and non-human primates. For rats, striatal

trophic activity declines significantly in old age; at least part of this decline is attributable to decreased levels of GDNF. Following a unilateral 6-OHDA lesion, young rats increase their striatal trophic activity as a form of compensation, but this capacity is absent in old rats. In contrast, a different pattern of effects is seen in aging non-human primates. Advancing age correlates with an increase in combined striatal trophic factor activity, and this change is already present in middle age. Thus, primates may have an ongoing compensatory trophic reaction to aging-related changes in the dopamine system, but this mechanism does not appear to operate in aging rats. Dopamine system lesions in young adult non-human primates resulting from MPTP treatment, as with young rats, increases striatal trophic activity, but a further lesion-induced increase is not found in older animals above their elevated age-related baseline levels. These effects in non-human primates are not attributable to changes in either GDNF or BDNF. Taken together, these findings suggest the possibility that neurotrophic factor-related mechanisms are altered during the aging process and that a reduced sensitivity to neurotrophic factors may be responsible for some of the age-related declines in neuronal and behavioral function (*see* Models of Aging: Vertebrates).

Neurotransmitters and Neurotrophic Factors in Neurodegenerative Disease

The question of how changes in neurotransmitter or neurotrophin systems, considered to be part of normal aging, may contribute to the onset and progression of human neurodegenerative disease is the topic of much debate. Although it is well known that most degenerative diseases of the brain have a characteristic age of onset, it is unclear what role natural age-related changes in morphological and biochemical properties of neurotransmitter or neurotrophin neurons play in the progression of disease, or to what degree aging may affect different areas of the diseased brain. What are clear, however, are the facts that neurodegenerative diseases of the brain result from a composite of multi-neurotransmitter and possible neurotrophin deficits that are characteristic of a particular disease state and that classic neurodegenerative diseases of the brain, such as Parkinson's and Alzheimer's disease, should not be considered the natural endpoints of normal aging but rather represent disease states for which risk factors increase with age.

Another basic concept that is crucial for understanding the pathophysiology of neurotransmitter systems in human neurodegenerative disease is the notion that neurotransmitter neurons can compensate for disease-associated cell loss that can delay the onset of clinical systems for several decades after cell loss begins. The phenomenon of functional compensation was first observed in dopaminergic neurons of the nigrostriatal system in Parkinson's disease in the early 1970s when investigators reported that mild clinical symptoms were associated with a disproportionately large decrease (up to 80% loss) of striatal dopamine. Subsequent to this observation, numerous investigators have developed models and theories regarding the etiopathology of transmitter systems as a causal factor for the development of neurodegenerative diseases of the CNS. Common to all theories regarding the pathology of neurotransmitter systems and human disease are the hypotheses that (1) clinical symptoms become evident only when the neurotransmitter content of a critical brain region is substantially depleted (i.e., by 80% in the case of Parkinson's disease), and (2) in the early stages of the disease, neurotransmitter cell loss or dysfunction is offset by adaptive changes in both pre- and postsynaptic neurons that functionally compensate for the death of neighboring neurons. The notion that neurotransmitter neurons can functionally compensate for cell death has led to the idea that the onset and progression of human neurodegenerative disease can be characterized by two stages of the disease process. Stage 1, or presymptomatic disease, spans the time from when disease-associated neurotransmitter cell loss begins (i.e., disease inception) to when cell loss and neurotransmitter depletion is sufficient to induce clinical symptoms (i.e., symptomatic threshold). As in the case of Parkinson's disease, presymptomatic clinical disease can last as long as 20 to 40 years prior to when the disease becomes clinically manifest. In comparison, stage 2, or symptomatic disease, is characterized by the progressive increase in the severity and complexity of clinical symptoms characteristic of the disease process and is positively correlated with the degree of neurotransmitter loss. Understanding the underlying mechanisms that relate to the loss of neurotransmitter neurons in human disease and how they relate to brain function is a prerequisite for developing new strategies to ameliorate age-related behavioral impairments and neurodegenerative diseases of the CNS. In addition, knowing that the brain retains a high level of functional reserve so that early neuron degeneration can occur without clinical symptoms challenges researchers to develop preventive therapeutic strategies that can be started before symptoms appear. Thus, a major goal of current clinical research is not just to treat the disease after it becomes debilitating, but to develop new tools that can improve early detection and identify at-risk groups. In this way preventive therapies can be

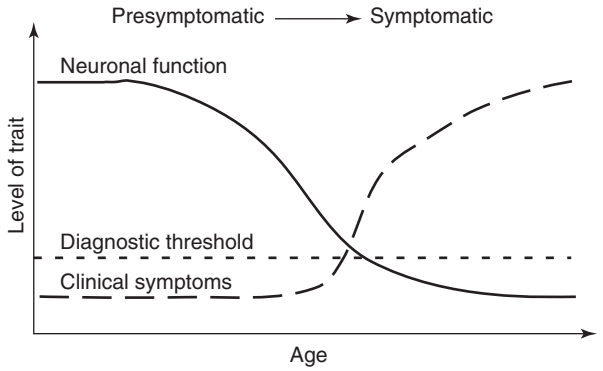

Figure 3 Schematic diagram of the progression of neuron loss and dysfunction in neurodegenerative disease. The presymptomatic phase is characterized by loss of neuron function without clinical symptoms. This period may last 20 or more years before the clinical symptoms of disease become manifest. By comparison, the symptomatic phase occurs when cell loss and neurotransmitter depletion are sufficient to induce clinically significant symptoms (i.e., diagnostic threshold).

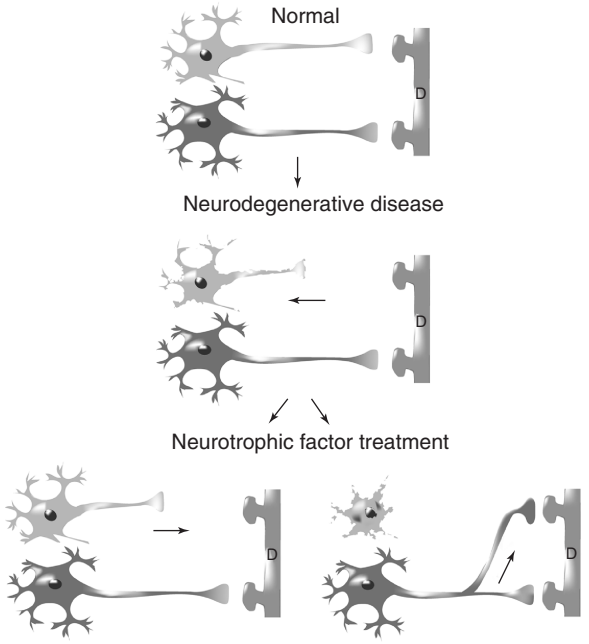

Figure 4 Schematic drawing depicting two nerve cells with synaptic contacts on target neuron dendrite (D). In neurodegenerative diseases such as Alzheimer's or Parkinson's there are atrophic changes in some neurons, including shrinkage of the cell body, retraction of the axon terminal, and loss of synapses. Two therapeutic approaches that have been proposed for neurotrophins as neuroprotective agents are shown. First, neurotrophins can reverse cell body and synaptic atrophy in the affected neuron and promote synthesis of proteins necessary for cell survival and axon growth. Second, neurotrophins may promote axon sprouting and reinnervation of lost synapses by neighboring neurons to compensate for cell loss and maintain functional performance.

directed at individuals in the preclinical phase of the disease in order to prevent or slow the progression of the disease process (see **Figure 3**).

Neurotrophic regulation has been linked to the degeneration that occurs in the age-related neurodegenerative diseases. Basic research indicating that these proteins regulate the survival and growth of neurons has created opportunities for using them therapeutically as neuroprotective agents. To date, three therapeutic approaches have been proposed for neurotrophins as neuroprotective agents. First, since it is known from developmental studies that neurotrophic factors are essential for cell survival, it is believed that treatment with neurotrophic factors in the presymptomatic phase of the disease may reverse the atrophy of the nerve cell's synthetic machinery and stimulate synthesis of proteins essential for cell survival, neurotransmitter release, and, perhaps, reestablish lost synaptic contacts (**Figure 4**). Second, since studies have shown that neurotrophins can modulate neural plasticity in the adult brain and that neighboring neurons can compensate for cell loss and atrophy of neighboring neurons, it is believed that activation of developmentally regulated neurotrophic mechanisms in response to aging or disease can form the basis for the compensatory repair mechanisms needed to slow or prevent the progression of the disease process. This hypothesis forms the basis not only for the development of new neurotrophin treatments but also for the promising new changes in lifestyle strategies that promote mental and physical exercise to enhance personal well-being, increase cognitive function, improve cardiovascular health, and reduce the risk for developing dementia in old age. Third, studies have reported that neurogenesis (i.e., forming new neurons) is not limited to the development, but continues throughout life in a few areas of the brain such as the hippocampus and subependimal zone of the ventricular system. In addition, data suggest that neurogenesis is modulated, in part, by the neurotrophin BDNF. It is believed that treatments targeting BDNF upregulation in the hippocampus may be useful therapeutic approaches to preserving brain function by stimulating cell division in part of the brain important for learning and memory.

Several strategies are currently being pursued to deliver neurotrophic factors to the brains of patients with age-related neurodegenerative diseases. In one example, NGF is provided by gene therapy to acetylcholine-producing neurons in the brains of patients suffering from Alzheimer's disease. These studies are based on a wealth of data from animal studies that predict that this approach will be safe and beneficial. Initial clinical observations have provided encouraging results. In a second approach, GDNF is being delivered to DA neurons in the brains of Parkinson patients by infusions through cannulas

implanted into the brain. Early observations in patients are encouraging. These early clinical experiences paint an optimistic picture for the future of neurotrophic factor therapy. However, many years of careful observations on a small number of patients will be necessary to establish the safety and efficacy of these experimental treatments.

See also: Brain and Central Nervous System; Models of Aging: Vertebrates.

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Obesity

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Glossary

Body Mass Index (BMI) – A measure of body weight adjusted for height determined by a person's weight in kilograms, divided by height in meters squared.

Metabolic Syndrome (also known as Syndrome X, and the Insulin Resistance Syndrome) – A constellation of abnormal metabolism including glucose intolerance, abdominal obesity, dyslipidemia, and hypertension.

Obesity – Refers to an excess of body fat relative to lean body mass, typically with a BMI of 30 or higher.

Visceral Fat (VF) – The fat accumulated within the abdominal wall and around internal organs such as intestines and kidneys, resulting in abdominal adiposity.

Background

The prevalence of obesity is increasing at an alarming rate. Although it is difficult to estimate the actual numbers of overweight and obese people, data from the latest National Health and Nutrition Examination Survey (NHANES) show that about 33% of American adults are obese, and ~66% are either overweight or obese (see **Figure 1**), a 119% increase over the past three decades. Other continents show similar trends. The obesity epidemic is not limited to industrial countries; the increase is often faster in developing countries.

Obesity is independently associated with an increase in deaths from all causes. Additionally, obesity has been linked to many diseases that carry significant morbidity, mortality, and shortened life span, including diabetes and the metabolic syndrome, stroke, gall bladder disease, some cancers, obstructive sleep apnea, osteoarthritis, and stroke. Indeed, obesity-attributable US medical spending in 2002 has been estimated at $61 billion, accounting for 4.6% of total annual medical expenditures. This does not include the substantial indirect cost to society, including disability and lost time from work, which is estimated to be $51 billion. The growing prevalence of obesity thus has important public health implications.

Aging is often associated with an increase in adiposity, especially abdominal obesity, which can be increased even in the absence of a significant increase in body mass index (BMI), a measure of body weight adjusted for height. In developed areas of the world,

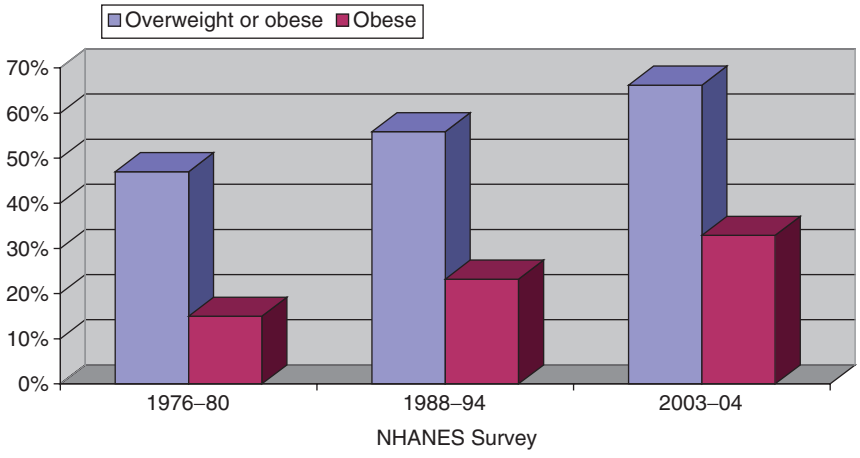

Figure 1 Age-adjusted prevalence of overweight and obesity among US adults, age 20–74 years. Adapted from the Centers for Disease Control and Prevention website (http://www.cdc.gov).

people tend to gain weight until about 60 years of age, and then their BMI begins to decline. However, in the elderly, the ratio between fat mass and lean body mass is usually increased. In addition, fat infiltrates other tissues, such as muscle and liver, and accumulates substantially at the visceral (abdominal) region. This increased visceral adiposity is largely due to an increase in visceral fat (VF). VF is defined as the fat accumulated within the abdominal wall and around internal organs such as intestines and kidney, resulting in abdominal adiposity. VF may have important health implications, as it is linked to the development of poor health outcomes and has a central role in the metabolic syndrome of aging. As the population ages and the obesity epidemic grows, our understanding of the relationship between increased adiposity and the poor health outcomes associated with the metabolic syndrome becomes increasingly important.

Definition of Obesity

The definition of obesity is arbitrary but generally refers to an excess of body fat relative to lean body mass. The problem of defining obesity arises because weight is a continuum, so an absolute cutoff dividing normal from overweight from obesity is difficult to determine. Several techniques are available for measurement of fatness. The gold standard technique for estimating body fat is called densitometry and involves underwater weighing of patients using the underlying principle that fat and non-fatty tissues have different densities. Using one of several available formulas, an estimate of body fat can be obtained. Another method is to estimate lean body mass based on nuclear isotope studies. These methods are not readily available, so other indirect estimates need to be used to estimate body fat.

Indirect methods for estimating body fat are more commonly used and more practical. They include skin fold measurements and tables that provide weight for height values that have been developed by life insurance companies to determine the lowest mortality risks. Currently the most widely accepted indirect measure of obesity is BMI. This value is defined as a person's weight in kilograms divided by the height in meters squared. The Center for Disease Control and Prevention defines overweight as a BMI between 25 and 29.9 and obesity as a BMI of 30 or higher. Healthy weight is defined as a BMI between 18.5 and 24.9.

What Causes Obesity?

Obesity results from an imbalance between caloric consumption and caloric expenditure over a prolonged period. Weight gain occurs when there is a greater consumption of calories than expenditure. The expenditure of calories is complex and results from likely combinations of metabolic, genetic, and individual factors. Genetics and environment may predispose to weight gain, but it is only the consumption of calories in excess of utilization that can cause weight gain.

In the developed world, there is easy access to large quantities of low-cost, high-calorie, high-fat foods. Over the last 20–30 years portion size has also dramatically increased. The combination of increased availability to nutrients and sedentary lifestyle has resulted in decreased energy expenditure with increased caloric intake. This combination is likely the main reason for the dramatic increase in obesity occurring worldwide. Additionally, medical care has advanced so that the average life span is rising despite the age-associated increase in body fat and obesity-related disease.

Although energy imbalance is the underlying reason for the obesity epidemic, there are some medical conditions, genetic diseases, and medications that may cause the imbalance to occur or worsen. Problems such as hypothyroidism (inadequate production of thyroid hormone) and Cushing's syndrome (an excess of endogenous steroid production) are examples of medical problems that can be associated with weight gain. Examples of genetic diseases associated with obesity include leptin deficiency (a hormone involved in the energy balance and discussed in detail later) and Prader-Willi syndrome (a complex disorder resulting in decreased muscle tone, short stature, mental retardation, behavioral problems, and excessive eating resulting in obesity). Some examples of medications that are associated with weight gain include antipsychotic medications (especially newer-generation medications) and steroids (chronic use), which may be given for a variety of inflammatory conditions. However, the aforementioned factors are rarely the primary cause of obesity and combined do not significantly contribute to the obesity epidemic.

Obesity and the Metabolic Syndrome

Concomitant with the global increase in obesity is the increase in the metabolic syndrome. The metabolic syndrome, also known as the metabolic syndrome of aging, syndrome X, and the insulin resistance syndrome, is a constellation of abnormal metabolism including glucose intolerance (impaired glucose tolerance, impaired fasting glucose, and type 2 diabetes), central (abdominal) obesity, dyslipidemia, and hypertension. All of these metabolic abnormalities are well-established cardiovascular (CV)

Table 1 NCEP: ATP III criteria for metabolic syndrome[a]

Risk factor	*Defining level*
Abdominal obesity	Waist circumference
Men	>102 cm (>40 in)
Women	>88 cm (>35 in)
Triglycerides	≥1.7 mmol/l
HDL cholesterol	
Men	<1.0 mmol/l
Women	<1.3 mmol/l
Blood pressure	≥130/≥85 mmHg
Fasting glucose	≥6.1 mmol/l

[a]Diagnosis is established when three or more of these risk factors are present.

disease risk factors. A low level of inflammation may coexist and contribute to, or serve as markers of, this increased risk.

The definition of the metabolic syndrome remains controversial. There are currently two well-established definitions of the syndrome using slightly different criteria. The World Health Organization (WHO) criteria are often limited to the research setting since they involve multiple glucose measurements or clamp studies. The National Cholesterol Education Program: Adult Treatment Panel III (NCEP: ATP III) guidelines (see **Table 1**) are more often used clinically because they require only a single glucose measurement. Based on the NCEP: ATP III definition of the metabolic syndrome, it is not surprising that the presence of the syndrome correlates well with the development of diabetes and death from coronary disease.

Future criteria for the metabolic syndrome may take into account racial or age-related differences in risk for disease. For example, Asians may have equivalent risk for the poor outcomes associated with metabolic syndrome at BMI of 23–24 compared to Caucasians with BMI of 30, and the elderly may have increased visceral fat despite normal BMI.

Fat Distribution, Caloric Restriction Principles, and Experimental Models

Not all fat is equally bad for your health. It is widely known that fat distribution is extremely important. There is increasing evidence for the deleterious effects of VF on aging. Waist-to-hip ratio (WHR) is an epidemiological tool that demonstrates a correlation between VF and development of diabetes mellitus, stroke, coronary artery disease, and mortality. This ratio is easily determined by dividing the measurement of waist circumference by hip circumference. A ratio greater than 1.0 for men and 0.9 for women correlates with adverse outcomes. People with higher WHR probably have a more central fat pattern and have body fat distributions sometimes described as android, apple-shaped, or having a 'beer belly'. People with a lower WHR probably have more fat distributed in the lower body, are referred to as gynecoid, or pear-shaped, and seem to have less risk from obesity-related diseases than those with central fat. The fact that different body distribution of fat may be worse than others partially explains why it is difficult to simply define obesity.

Experimental data in rodent models further support the relationship of VF to obesity-related illness. For example, caloric restriction (referring to a diet containing all of the necessary nutrients and vitamins but only a fraction of the calories of a diet with free access to food) reversed the age-related increases in plasma insulin, glucose, and glycosylated hemoglobin (a serum marker of glucose control over an extended period of time) to youthful levels. In fact, it restored liver and muscle insulin sensitivity to youthful levels independent of age. Furthermore, surgical removal of VF in rats has dramatically reversed the defects in insulin action. In a recent human study, removal of subcutaneous fat did not provide the same improvement in insulin sensitivity seen, underlining the importance of visceral fat as the biologically more active fat depot.

Fat as a Dynamic Organ

Adipose tissue is not simply a reservoir for excess nutrients, but rather an active and dynamic organ capable of expressing biologically active fat-derived peptides (FDPs). At times of acute injury, macrophages contribute to the release of these peptides and the term inflammatory markers is often applied, but in the basal state, adipose tissue is the predominant source of production. Some of these FDPs may have a role in the development of the metabolic syndrome of aging and other obesity-related diseases.

Leptin, a peptide derived from adipose tissue, acts through a cytokine receptor and is expressed and secreted in direct proportion to fat mass. Leptin exerts its effect predominantly through receptors in the central nervous system, specifically the hypothalamus, but it may also have peripheral actions. Genetic models of leptin deficiency are associated with marked obesity and diabetes. Leptin serves as a marker of energy sufficiency by rapidly decreasing during starvation and weight loss. With the development of increased VF during aging, leptin levels are increased in proportion to fat mass, but its activity to decrease appetite seems reduced. This failure of leptin action may be partially due to human eating behavior in which meals are eaten regularly regardless of plasma leptin levels, degree of appetite, or degree of obesity.

Tumor necrosis factor-α (TNF-α), previously known as lymphotoxin and cachetin, is thought to be involved in the wasting that occurs during illness and malignancy. In the basal state TNF-α level is proportional to fat mass and has been shown experimentally to be involved in the development of insulin resistance. *In vitro* studies have demonstrated that TNF-α decreases the insulin receptor tyrosine phosphorylation and downregulates several steps in the insulin signaling pathway. Additionally, TNF-α antagonists have been shown to improve insulin resistance in some models.

Adiponectin is highly expressed in adipose tissue and is one non-cytokine FDP that is thought to be protective. Unlike most FDPs, circulating levels are inversely proportional to obesity. Levels tend to be low in obesity and increase with weight loss. Animal models have shown that low adiponectin levels increase smooth muscle proliferation in response to injury, increase free fatty acid levels, and cause insulin resistance, while adiponectin administration improves insulin sensitivity. The pro-diabetic and pro-atherogenic effects of low adiponectin levels seen in the metabolic syndrome provide another link between inflammation and obesity.

Plasminogen activator inhibitor-1 (PAI-1) is the primary inhibitor of fibrinolysis and is highly expressed in adipose tissue, and may have a significant role in thrombosis. PAI-1 levels are correlated with adiposity and are significantly overexpressed in the adipose tissue of obese compared to lean animals. The relationship of PAI-1 to obesity provides a link between obesity and acute coronary events.

Interleukin-6 (IL-6) is another cytokine derived from adipose tissue. Its expression and circulating levels correlate directly with fat mass. Elevation of circulating IL-6 is a predictor of the development of cardiovascular disease and diabetes. Infusion of IL-6 results in hyperlipidemia, hyperglycemia, and insulin resistance in experimental models. Additionally, IL-6 decreases the expression of adiponectin.

Angiotensinogen (AGT), as well as the other peptides in the renin-angiotensin system, are produced in adipose tissue. The strong correlation between obesity and hypertension suggests that adipose tissue may play a role in blood pressure regulation. The correlation between circulating AGT levels and obesity/hypertension has been shown in animal studies in which overexpression of AGT results in hypertension while underexpression of AGT results in decreased blood pressures.

Other inflammatory cytokines, including serum amyloid A interleukin-1, interleukin-8, and interleukin-18, also increase with increasing body weight and may have a yet-undetermined role in the development of obesity-related disease.

Weight Loss

Weight loss improves many of the adverse health outcomes associated with obesity, including preventing or delaying the onset of diabetes, improving blood sugar control in those with diabetes, reducing low-density lipoprotein (bad cholesterol), raising high-density lipoprotein (good cholesterol), improving hypertension, improving symptoms of osteoarthritis, and providing an improved sense of well-being. Individuals must only lose a small percentage of their weight (~5–10%) to begin seeing these improved health outcomes. As many people know from their personal experiences, weight loss is difficult and lost weight is often regained for a variety of reasons. Returning to the original concept of energy balance, the formula for weight loss is predictable. To lose weight, energy expenditure must be greater than energy consumption. The first recommendation therefore is lifestyle modification with a combination of increased exercise and decreased intake (diet modification).

The amount of exercise needed to lose weight is variable. Current recommendations from the US Surgeon General is for adults to engage in an activity of moderate intensity (such as brisk walking) for 30 min daily or more strenuous activities (such as jogging) for 15–20 min daily. Additional exercise will increase energy expenditure and may result in further favorable health outcomes.

Caloric restriction through dieting is also essential for losing weight. The ideal diet has not yet been established, but the principle of reducing caloric intake along with ease of long-term compliance remains the cornerstone of any diet. The American Dietetic Association currently changes their recommendation periodically in an effort to determine the most helpful, practical diet, based on current data. The problem with short-term dieting is that weight loss can rarely be maintained once the diet has ended. Exercise may help maintain some of the weight loss.

Some medications exist for weight loss. These medications are moderately effective, although they often have side effects that limit their widespread use. The history of diet medications has been plagued with adverse health outcomes, including valvular heart disease and heart arrhythmias. Many of these medications have focused on increasing the metabolic rate or suppressing appetite.

One such medication that has been approved for use in the United States for weight loss is orlistat. This medication uses a novel mechanism to prevent the body from digesting a portion of the fat that has been ingested, thereby lowering the number of

calories absorbed. The undigested fat is excreted out of the body via bowel movements. This medication has minimal systemic side effects since there is little absorption; however, it results in uncomfortable changes in bowel movements such as oily discharge and increased frequency of bowel movements.

Another medication available for weight reduction is sibutramine. The mechanism of action is inhibition of norepinephrine, dopamine, and serotonin reuptake, resulting in weight loss from appetite suppression, possibly combined with an increase in thermogenesis from stimulation of adipose tissue. Use of this medication combined with diet and exercise results in modest reduction ($\sim$7%) in weight at 1 year, although sustained weight loss at 2 years is less robust.

Because of the high failure rates of lifestyle modification and medical therapies, surgical approaches for weight loss are becoming widely available. The most successful of these surgeries is the gastric bypass. It works by decreasing the size of the stomach, to achieve satiety earlier, as well as by bypassing part of the small intestine, which results in fewer calories being absorbed. This surgery is very effective in achieving weight loss and improving many of the obesity-related diseases. Complications include nutritional deficiencies, postoperative wound infections, leaks at the surgical sites, and postoperative mortality ($\sim$1.5%). Due to these risks, this therapy should be reserved for patients who are morbidly obese (BMI $>$40 or BMI $>$35), who have obesity-related diseases, and who have failed behavioral modification therapies.

Special Considerations in the Elderly

Obesity in the elderly is a major health crisis facing our population that may predispose the elderly to the same adverse health outcomes facing the younger, obese population. However, several studies have suggested that the risk of obesity on life span is less in the elderly and may even become insignificant. However, these studies have found an increase in disability in older subjects with obesity. Before concluding that obesity is not a risk factor in the elderly, there are a few considerations that help explain the data. First, because obesity is a risk for death in younger age, it is the survivors who are protected from the adverse effects of obesity that are being followed, i.e., those with obesity-related illnesses tend to die before reaching old age. Second, as mentioned earlier, people begin to decrease their lean body weight with age, thereby lowering their BMI despite the fact that they continue to acquire and/or redistribute VF preferentially. This increased VF in the elderly can lead to poor health outcomes. If BMI is the only index associated with obesity in the elderly, then the true risk might be missed. Third, a subgroup of elderly who are losing weight rapidly due to illnesses such as the frailty syndrome, sarcopenia, cancer, or pulmonary or cardiovascular diseases are at greater risk of dying than obese people, an observation that masks the independent effect of obesity.

Considering the preceding confounding variables, how to apply standards for ideal weight is unclear in elderly populations. Medications used for weight loss have not been sufficiently studied in the elderly population, and surgical options may be limited in the elderly because of comorbidities that increase the risks of surgery.

Conclusions

The prevalence of obesity is increasing at alarming rates. This increase in obesity is resulting in epidemic increases in obesity-related disease including diabetes, hypertension, and cardiovascular disease. The distribution of fat is of key importance, with VF seemingly worse than subcutaneous fat, and this is supported by experimental data. This is well illustrated in humans by the fact that the elderly, who are at high risk for obesity-related disease, tend to accumulate VF despite the fact that their BMI can decrease. In fact, it is not clear how to interpret BMI in the elderly population since being overweight does seem to correlate well with mortality.

Indeed, these trends suggest that for the first time in modern history, the life expectancy of people in developed societies will begin to decrease, unless the rapid increase in the prevalence of obesity can be reversed.

See also: Body: Composition, Weight, Height, and Build; Diet and Nutrition; Exercise and Physical Activity; Metabolism: Carbohydrate, Lipid, and Protein.

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Obsessive Compulsive Disorders

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Glossary

Compulsive Hoarding – A behavioral syndrome that involves acquiring a large number of possessions, storing of items and not discarding unused objects, and keeping or storing them in such a way that it interferes with daily living.

Diogenes Syndrome – Syndrome characterized by extreme self-neglect, domestic squalor, and social withdrawal, as well as refusal of help.

Exposure and Response Prevention – In this behavioral therapy, patients are systematically exposed to their obsessions while trying to resist their compulsions.

Obsessive-Compulsive Disorder – An axis I psychiatric disorder characterized by the presence of either obsessions or compulsions, which cause marked distress, are time-consuming, and interfere with functioning.

Obsessive-Compulsive Personality Disorder – An axis II personality disorder that is associated with an obsessive concern for details, perfectionism, and rigidity with ego-syntonic behaviors.

Introduction

Obsessive-compulsive disorder (OCD) is a common neuropsychiatric condition that is frequently unrecognized and untreated, resulting in significant personal suffering and functional impairment. This article reviews the current state of knowledge of OCD epidemiology, clinical features and natural history, differential diagnosis, and treatment options, focusing on how OCD affects the elderly.

Diagnosis and Epidemiology

Obsessive-compulsive disorder is defined by the presence of either obsessions or compulsions, which cause marked distress, are time consuming, and interfere with functioning. Obsessions are anxiety-provoking repetitive and intrusive thoughts, impulses, or images. Compulsions are characterized by repetitive and ritualistic behaviors or mental acts aimed at reducing anxiety. Adult patients recognize symptoms of OCD as unreasonable – although there is great variability in insight, both across individuals and in a given individual over time. The current diagnostic criteria for OCD are described in **Table 1**.

OCD has not been well studied among elderly patients. Much of what is known about aging and OCD comes from the National Institute of Mental Health (NIMH) Epidemiological Catchment Area Program (ECA) using the Diagnostic Interview Schedule (DIS) based on the *Diagnostic and Statistic Manual of Mental Disorders*, 3rd edition (DSM-III) conducted in the United States. The 1-year prevalence for individuals over 65 years was 0.85%, 0.75% for men and 0.93% for women, in contrast to 1.65% for all ages combined. Analysis limited to the eastern Baltimore site of the ECA found a prevalence rate of 1.3% in those between the ages of 65 and 74 years, and 0.6% in those older than 75 years. Interestingly, when incidence rates were estimated for the ECA study based on the 1-year follow-up, a bowl-shaped curve was found with an increase in incidence for women over the age of 64, whereas the incidence rate for OCD fell for men with increasing age. The incidence rate for those over the age of 64 was 0.63 per 1000 person-years, due primarily to women. The ECA estimated that only one-twelfth of individuals with OCD are initially afflicted after the age of 50, with a mean age at onset between 21.9 and 35.5 years. A cohort effect, differential mortality, differences in symptom endorsement, or differential recall

Table 1 DSM-IV-TR diagnostic criteria for obsessive-compulsive disorder

A. Either obsessions or compulsions:
Obsessions as defined by (1), (2), (3), and (4):
(1) Recurrent and persistent thoughts, impulses, or images that are experienced, at some time during the disturbance, as intrusive and inappropriate and that cause marked anxiety or distress.
(2) The thoughts, impulses, or images are not simply excessive worries about real-life problems.
(3) The person attempts to ignore or suppress such thoughts, impulses, or images, or to neutralize them with some other thought or action.
(4) The person recognizes that the obsessional thoughts, impulses, or images are a product of his or her own mind (not imposed from without as in thought insertion).
Compulsions as defined by (1) and (2):
(1) Repetitive behaviors (e.g., hand washing, ordering, checking) or mental acts (e.g., praying, counting, repeating words silently) that the person feels driven to perform in response to an obsession or according to rules that must be applied rigidly.
(2) The behaviors or mental acts are aimed at preventing or reducing distress or preventing some dreaded event or situation; however, these behaviors or mental acts either are not connected in a realistic way with what they are designed to neutralize or prevent or are clearly excessive.
B. At some point during the course of the disorder, the person has recognized that the obsessions or compulsions are excessive or unreasonable. Note: this does not apply to children.
C. The obsessions or compulsions cause marked distress, are time consuming (take more than 1 h a day), or significantly interfere with the person's normal routine, occupational (or academic) functioning, or usual social activities or relationships.
D. If another axis I disorder is present, the content of the obsessions or compulsions is not restricted to it (e.g., preoccupation with food in the presence of an eating disorder; hair pulling in the presence of trichotillomania; concern with appearance in the presence of body dysmorphic disorder; preoccupation with drugs in the presence of a substance use disorder; preoccupation with having a serious illness in the presence of hypochondriasis; preoccupation with sexual urges or fantasies in the presence of a paraphilia; or guilty ruminations in the presence of major depressive disorder).
E. The disturbance is not due to the direct physiological effects of a substance (e.g., a drug of abuse, a medication) or a general medical condition.
Specify if:
With poor insight: if, for most of the time during the current episode, the person does not recognize that the obsessions and compulsions are excessive or unreasonable.

Adapted from *Diagnostic and Statistical Manual of Mental Disorders* (APA, 2000).

may explain the lower rates of OCD in elderly patients because OCD is a chronic disorder.

A study conducted in Edmonton, Canada, using the DIS and DSM-III, found the 6-month prevalence rate for those over the age of 65 was 1.5% and the lifetime rate was 2.5%. Men had a 6-month prevalence rate of 0.9% and a lifetime prevalence of 2.2%, and women had rates of 1.9 and 2.7%, respectively. A prevalence study conducted in Turkey using the Composite International Diagnostic Interview (CIDI) found unusually high rates of OCD in those over the age of 65 using *International Classification of Diseases* (ICD-10) diagnoses. The overall 1-year prevalence rate in the elderly was 4.3% compared to 3.0% for the general population. The Turkey study found no cases of OCD in elderly men, but found a prevalence rate of 9.3% for women. In Colombia the 1-year prevalence rate for those 61 and older using the CIDI and DSM-IV was 2.0% for lifetime and 0.6% for 1-year prevalence, while the overall population had rates of 3.6 and 3.1%, respectively. In Iran the Schedule for Affective Disorders and Schizophrenia (SADS) was used to ascertain cases of DSM-IV-defined OCD in a national sample. That study obtained a current prevalence rate of 1.0% among those age 65 and older, with a predominance in women of 2.8% in contrast to men with 0.1%; the rate in those over the age of 18 for comparison was 1.8% total, 2.8% in women and 0.7% in men.

The Longitudinal Aging Study Amsterdam (LASA) is the most extensive community-based study to have examined anxiety disorders in adults age 55 and older, using the DIS and DSM-III diagnoses. The authors found a 6-month overall rate of OCD of 0.6%. The disorder was found exclusively in women in this study, as in the Turkish study, which is unusual because in most epidemiological studies there is a near-equal gender distribution with women having a higher prevalence among the elderly. The rates were 2.7% among 65- to 74-year-olds and 0.8% for those aged 75–85. The LASA study found few related risk factors for OCD among the elderly other than a positive family history and loneliness. A strong comorbidity with major depression, but not with any of the other anxiety disorders, was found. In addition, an increased risk was found among those with heart disease and incontinence.

Most recently, the National Comorbidity Survey Replication (NCS-R) study conducted in the United States, based on the CIDI, found a lifetime rate of DSM-IV OCD among those over the age of 60 of only 0.7%, in contrast to 1.6% in the overall

population. In addition, 90% of those in the NCS-R had an age of onset prior to age 50, with more than half by the age of 19.

However, most studies using diagnostic criteria developed for use in geriatric mental health research have found much lower rates in the elderly. A number of studies examining current prevalence of obsessive neurosis in the elderly have been conducted using the Geriatric Mental State Interview (GMS) with diagnoses made with the Automated Geriatric Examination for Computer Assisted Taxonomy (AGECAT). In Liverpool, UK the rate was found to be only 0.1%. In the United Arab Emirates the rate among individuals 60 and older was 1.8%. In Edmonton, Canada it was 1.0% in males, 0.9% in females, and 0.9% for the total sample of individuals over the age of 64. In Dublin, however, no cases were found in a population of 1232 persons age 65 and over.

OCD has a higher prevalence in institutional settings compared to the general community. Elderly nursing home patients using the DIS in Edmonton, Canada, had a 6-month prevalence of 1.4% for men and 4.7% for men.

Clinical Characteristics in the Elderly

Only about 5–12% of people attending specialty OCD clinics are 60 years or older. However, OCD is rarely diagnosed in general outpatient settings in the elderly, as noted in a study of the Kaiser Health Maintenance Organization in which only 29 cases per 100 000 patients were reported. OCD seldom begins in late life, and most elderly people with this disorder who present for treatment have had symptoms for decades. A study of consecutively evaluated outpatients found only 1% of those in an OCD clinic had the onset of the disorder after age 50. There are few reported cases of onset after the age of 70. The first contact in treatment among the elderly with OCD is also later than in younger patients, 43 compared to 25 years of age.

The clinical presentation of OCD does not significantly differ between younger and older patients. Older patients have more hand-washing rituals and less obsessions with symmetry, concerns about checking paperwork, preoccupation about remembering insignificant details, counting rituals, fear of not saying the right thing, checking things a certain number of times, and systems of lucky and unlucky numbers. Common obsessions in older patients are fears of contamination, harming others, being responsible for things going wrong, having sinned, and obsessions with symmetry. The most common compulsions in the elderly are hand-washing rituals, concerns with avoidance of contamination, checking things around the house to make sure they are safe, needing to confess, and doing and undoing rituals (see **Tables 2** and **3**). In addition, the severity of OCD symptoms does not differ with age based on the Yale Brown Obsessive-Compulsive Scale (YBOCS).

Recently, intake data were analyzed from the Brown Longitudinal OCD Study (BLOCS), the only observational study in the literature in which subjects were recruited concurrently from multiple clinical settings, with assessments conducted by trained interviewers following a structured research protocol. Results suggested few differences among patients who were 60 years or older at intake ($n = 19$) and younger adults ($n = 274$). As in the previous study, the average age of first seeking treatment for OCD was considerably later in the elderly, 46 ± 17.8 years compared to 28.8 ± 10.6 years. However, there was no difference in severity of OCD symptoms on the YBOCS. Current and lifetime obsessive and compulsive symptom presentation showed few differences between the younger and older groups. The elderly did report fewer lifetime checking rituals and somatic obsessions. The most common obsessions found in the elderly were aggressive obsessions, while in the younger cohort they were obsessions of contamination. Cleaning rituals were the most common in the elderly, and checking rituals were the most common in the younger group. The rate of axis II personality disorders also did not differ using the SCID-II, with obsessive-compulsive personality disorder being the most prominent across age groups. As for comorbidity with axis I disorders based on the SCID, this sample of elderly patients had no current comorbid affective disorders in contrast to 17.5% among the younger cohort; however, there were no significant differences in lifetime affective disorder comorbidity. In addition, lifetime substance use disorders were lower among the elderly with OCD. Consistent with the lack of affective disorders among the elderly, the Hamilton Depression Scale scores were lower in the elderly sample, although this difference was not statistically significant.

Only one study has followed patients with OCD from their initial presentation to old age. This 40-year follow-up study found that an episodic course of OCD was more common during the initial years (about 1–9 years) but a chronic course was more common afterward. The study found that over time, 39–48% of people had symptomatic improvement. Compulsive symptoms were found to be less tractable than obsessions, and changes in the content of obsessive and compulsive symptoms are common.

Table 2 Common current and lifetime obsessions in OCD in elderly ($N = 32$) compared to younger adult patients ($N = 601$) (%)

Obsession symptoms	*Current*			*Lifetime*		
	< 60 years	*⩾ 60 years*		*< 60 years*	*⩾ 60 years*	
Aggressive obsessions	57.9	56.3		61.6	56.3	
Fear that one might harm or has harmed others	33.6	37.5		36.9	40.6	
Fear that one will be responsible for things going wrong	35.9	28.1		38.3	28.1	
Violent or horrible images	13.5	12.5		16.1	15.6	
Fear of hitting something or someone while driving one's car	16.5	9.4		21.5	12.5	
Fear that one will act on unacceptable impulses	9.8	9.4		11.6	9.4	
Fear that one might harm self	11.5	6.3		13.8	12.5	
Contamination obsessions	56.4	65.6		60.4	65.6	
Concerns with dirt or germs	44.8	56.3		50.9	56.3	
Concerns or disgust with bodily waste or secretions	23.1	18.8		25.1	18.8	
Excessive fear of contracting AIDS	16.0	12.5		19.8	12.5	
Excessive concern with household items	17.6	6.3		19.3	6.3	
Excessive concern with environmental contaminants	14.6	6.3		17.0	9.4	
Somatic obsessions	32.6	18.8		36.6	21.9	
Fear of developing a serious illness	32.6	18.8		36.6	21.9	
Sexual obsessions	24.1	21.9		26.6	21.9	
Forbidden or perverse sexual thoughts or images	21.5	21.9		23.3	21.9	
Unacceptable sexual impulses connected with images or thoughts	11.5	18.8		13.5	18.8	
Content involves homosexuality	7.0	6.3		8.0	6.3	
Content involves masturbation	3.5	3.1		4.3	3.1	
Content involves children	3.2	3.1		3.5	3.1	
Content involves incest	2.2	3.1		2.5	3.1	
Content involves animals	1.0	3.1		1.7	3.1	
Hoarding obsessions	25.1	21.9		27.5	21.9	
Fear of throwing things out because they might be useful someday	25.1	21.9		27.5	21.9	
Religious obsessions	19.0	28.1		25.8	31.3	
Fear of having sinned and therefore going to hell	15.8	28.1		21.6	31.3	
Fear of not having confessed completely	12.3	18.8		18.3	21.9	
Symmetry, exactness, or order obsessions	58.1	43.8		61.2	46.9	
Obsessions with the need for symmetry or exactness	43.1	25.0	*	47.3	28.1	*
Actions need to be just so	42.4	25.0		45.4	25.0	*
Miscellaneous obsessions	45.3	18.8	*	47.8	21.9	*
Fear of not saying things just right	24.6	9.4	*	26.1	15.6	
Need to know or remember	25.5	6.3	*	26.3	6.3	*
Fear of saying certain things	15.3	3.1		16.6	3.1	*
Intrusive sounds, words, or music	7.3	3.1		8.7	3.1	
System of good and bad numbers	13.6	0.0	*	15.6	0.0	*
Intrusive neutral or meaningless images	9.2	0.0		9.7	0.0	

Based on the YBOCS checklist adapted from data used in Kohn *et al.* (1997) *Fisher exact test $P < 0.05$. Lifetime = past and current combined.

Another study comparing retrospective reports of the course of OCD in younger adult and elderly patients found that the elderly had a more steadily deteriorating course with fewer periods of waxing and waning or remission.

Differential Diagnosis

A number of primary medical disorders can produce syndromes that resemble OCD. The phenomenological similarity between idiopathic OCD and OCD-like disorders that are associated with basal ganglia diseases, such as Sydenham's chorea and Huntington's disease, is well established. Hence, neurological signs of such basal ganglia pathology must be assessed when considering the diagnosis of OCD in a patient presenting for psychiatric treatment, especially among older individuals. Parkinson's disease also has been reported to have an association with OCD, although more recent studies do not support this relationship. Repetitive behaviors that are unrelated to OCD are frequently seen in Alzheimer's disease, such as repeatedly putting on and removing clothing, opening and closing drawers, and insistent repeating of questions. OCD symptoms also have presented for the first time among elders who have acquired brain injury, including cerebrovascular disease and infarcts.

OCD is also closely related to Tourette's syndrome; the two conditions frequently co-occur, both in individuals over time and within families. In its classic form, Tourette's syndrome is associated with a

Table 3 Common current and lifetime compulsions in OCD in elderly ($N = 32$) compared to younger adult patients ($N = 601$) (%)

Compulsion symptoms	*Current*			*Lifetime*		
	< 60 years	*⩾ 60 years*		*< 60 years*	*⩾ 60 years*	
Somatic compulsions	11.5	3.1		13.6	3.1	
Checking the body over again for a serious illness	11.5	3.1		13.6	3.1	
Cleaning or washing compulsions	60.7	75.0		65.4	75.0	
Excessive or ritualized hand washing	43.1	65.6	*	50.4	65.6	
Use of other measures to prevent contact with contaminated objects	39.1	53.1		40.4	53.1	
Excessive cleaning of household items or other inanimate objects	25.8	28.1		28.1	28.1	
Excessive or ritualized showering, bathing, or grooming	24.3	15.6		27.6	15.6	
Dressing or washing rituals	25.3	12.5		26.8	12.5	
Use of antiseptic, disinfectants, or bleach to wash one's hands	9.8	3.1		11.0	6.3	
Counting compulsions	35.9	15.6	*	39.4	15.6	*
Counting things over and over or going through numbers in one's mind	35.9	15.6	*	39.4	15.6	*
Checking compulsions	67.2	50.0		68.7	50.0	*
Checking things around the house to make certain they are safe	58.6	46.9		60.4	46.9	
Checking doors	32.1	21.9		35.3	21.9	
Checking the lights	23.0	15.6		25.6	15.6	
Checking the water	17.8	15.6		20.3	15.6	
Checking electrical appliances	29.6	15.6		32.3	15.6	
Checking the gas	20.6	9.4		23.3	9.4	
Checking windows	20.6	9.4		23.5	9.4	
Checking paperwork	26.3	6.3	*	27.8	6.3	*
Checking things to prevent something bad from happening	16.6	6.3		18.5	9.4	
Checking for contaminants	6.3	0.0		7.0	0.0	
Repeating rituals	44.6	40.6		48.3	43.8	
Doing/undoing rituals	28.1	34.4		30.6	37.5	
Checking or washing things only a certain number of times	17.5	3.1		20.3	3.1	*
Reading or re-reading	14.8	3.1		16.3	3.1	*
Doing things a certain number of times to limit the checks or washes	7.8	0.0		9.0	3.1	
Ordering or arranging compulsions	30.1	15.6		32.1	15.6	
Hoarding or collecting compulsions	20.6	18.8		22.5	18.8	
Miscellaneous compulsions	45.1	40.6		48.1	40.6	
Need to tell, ask, or confess	34.6	34.4		34.6	34.4	
Need to touch	16.6	6.3		21.3	6.3	*

Based on the YBOCS checklist adapted from data used in Kohn *et al.* (1997) *Fisher exact test $P < 0.05$. Lifetime = past and current combined.

pattern of recurrent vocal and motor tics that bears only a slight resemblance to OCD. However, many of the more complex vocal or motor tics are very similar to compulsions. Unlike compulsions that are actions aimed at relieving anxiety or preventing a feared consequence, tics are involuntary.

Pharmacologically precipitated OCD has been reported in the elderly. Case reports have been published of OCD being induced by methylphenidate and oral corticosteroid treatment.

Obsessive-compulsive behavior is also found in a number of other psychiatric disorders, which the clinician needs to rule out when diagnosing OCD. Psychotic symptoms often lead to obsessive thoughts and compulsive behaviors that can be difficult to distinguish from OCD with poor insight, in which obsessions border on psychosis. A substantial proportion of elderly with schizophrenia have comorbid OCD. OCD can be difficult to differentiate from depression, as the two disorders often co-occur, and major depression is often associated with ruminative thoughts that may appear to be obsessions. Ruminations are typically repetitive, mood-congruent thoughts that occur only during depressive episodes and are concordant with the patient's views of self. Comorbidity of OCD among those with major depression is rare. In a series of 336 elderly patients who either participated in treatment studies or were inpatients in a geriatric psychiatry unit with major depression, DSM-III-R OCD was found in 0.3% and 0.6% had a lifetime diagnosis. However, comorbidity of OCD in the elderly with other psychiatric disorders has been reported to be as high as 41% in clinical samples, primarily with major depression.

Cognitive deficits are seen in OCD regardless of age, and in the elderly they may be misinterpreted as age-related changes rather than characteristics of the disorder. Patients with OCD show significant impairments in visuospatial memory and verbal fluency, in particular in the accuracy of immediate and delayed recall on complex figure tests, the numbers of responses on category fluency tests, the response time

on the trail's A test, and the number of perseverative response and perseverative errors on the Wisconsin card-sorting test. The memory impairment seen in OCD is due to problems with organizational strategies in encoding information, executive function deficits, in non-verbal memory rather than actual memory deficits, suggestive of frontal-striatal dysfunction.

OCD shares some of the clinical features of obsessive-compulsive personality disorder (OCPD), which is associated with an obsessive concern for details, perfectionism, rigidity, and other similar personality traits. The conditions are distinguished by the fact that only OCD is associated with a true syndrome of obsessions and compulsions, while OCPD is associated with ego-syntonic behaviors (e.g., the individual derives pleasure from arranging items 'perfectly' in his or her home). One study found that community residents in the oldest age group reported more obsessive-compulsive personality characteristics using a self-report dimensional measure compared to one or more of the younger age groups. Another study of a sample of anxious elderly individuals and non-anxious elderly controls found OCPD in 39%, with higher symptom scores in the anxious group and non-anxious elderly compared to a younger adult anxious group. OCPD is also highly prevalent among the elderly with affective disorders. A report of elderly outpatients with dysthymic disorder found that 31.2% had OCPD and in major depression 11.0%. A retrospective chart review suggested that OCPD was the most prevalent of the personality disorders among geriatric inpatients with major depression.

Compulsive Hoarding

Compulsive hoarding consists of three components: acquiring a large number of possessions, storing of items and not discarding unused objects, and keeping or storing them in such a way that it interferes with daily living, with possible severe neglect of living space. This behavior was first described in 1975 in a sample of 30 individuals, all of whom were elderly and demonstrated extreme neglect of their home, appearance, and health, and was termed Diogenes syndrome. Although extreme hoarding, syllogomania, is frequently but not necessarily seen in Diogenes syndrome, it is characterized by extreme self-neglect, domestic squalor, and social withdrawal, as well as refusal of help. Diogenes syndrome may be present in 0.5 per 1000 elderly in the community and may be both a primary or secondary problem, with the latter being related to an axis I psychiatric disorder and the former being attributed to lifestyle choices or personality.

Hoarding is a behavior that brings the elderly to the attention of the authorities. Hoarding behavior is chronic and starts in childhood or early adolescence; treatment seeking is not evident until much later, around age 40 or 50. Based on a survey of health officers in Massachusetts, the researchers estimated that the rate of hoarding that presented to the Health Department in the community was 26.3 per 100 000 over a 5-year period. In that study, 40% of the cases were reported to authorities by the Department of Aging. A third of cases reported to authorities involved hoarding of animals. Those who hoard frequently are uncooperative with the authorities, resulting in multiple visits and reoccurrence of the problem. In Dublin, a study of service refusal by individuals offered meals-on-wheels, home help, house cleaning, and medical care found the majority (69.5%) to be elderly, and of those, 54.1% demonstrated hoarding behaviors.

Hoarding symptoms occurring at least several times a week have been found to be highly prevalent in nursing homes and in community senior adult day care, with rates of 15 and 25%, respectively. Among nursing home residents, hoarding behavior was related to a larger appetite, taking fewer medications, higher social functioning, comparatively less impairment in activities of daily living, and manifestations of physically non-aggressive, agitated behaviors. In both nursing homes and adult day care settings, persons who manifested hoarding behavior were those with relatively fewer health and functional disabilities.

A debate exists in the literature as to whether hoarding is actually OCD, a syndrome distinct from other psychiatric disorders, or a specific subtype of OCD. Hoarding is found as an obsession or compulsion in approximately a quarter of individuals with OCD. In an OCD clinic sample, 19% of the elderly had hoarding symptoms. Hoarding in the elderly has been found among patients with schizophrenia, bipolar mania, and dementia. Among these patients, it is usually not associated with OCD. A study of 133 dementia patients on a geropsychiatric unit found that 22.6% showed symptoms of hoarding. Hoarding was found in various types of dementia. Patients with hoarding and dementia had a higher prevalence of repetitive behaviors, hyperphagia, and pilfering. Hoarding behavior is associated with frontal lobe damage. In the original sample published in 1975 predating DSM-III, half did not meet the criteria for a specific psychiatric disorder.

One study examined the clinical characteristics of elderly hoarders who did not have dementia. Most elderly hoarders were female, were unmarried, and lived alone. Extensive clutter was associated with

significant impairment, interfering with basic hygiene and posing a serious physical threat. These patients were rarely insightful about their collecting and often resisted change, rendering interventions generally ineffective. Never being married was associated with more severe hoarding, greater impairment, and possibly with worse outcomes.

Treatment

Because there are no placebo-controlled treatment studies of OCD in the elderly, treatment guidelines are generally extrapolated from studies of younger populations and case reports of treated elderly. Selective serotonin reuptake inhibitors (SSRIs) are the drugs of first choice for OCD. The appropriate dose for treating OCD in the elderly has not been established, although it is widely believed that older patients generally require a lower dosage range for OCD than that used for younger adults. The efficacy of paroxetine, nefazodone, and venlafaxine in treatment of OCD in the elderly has not been reported, and evidence for the efficacy of sertraline for OCD in younger patients has not been consistent. Fluvoxamine has been studied in a very small sample open-labeled study in the elderly with OCD. Elderly patients on clomipramine have been found to reach a therapeutic steady state at doses lower than those reported for midlife patients, suggesting the need for plasma clomipramine monitoring and lower dosages. Although effective in younger patients, its use in the elderly may be more limited by anticholinergic, antihistaminergic, sedative, and sexual dysfunction side effects. At least one case of treatment-resistant major depression with comorbid OCD in the elderly with both disorders responding to electroconvulsive therapy has been reported.

In addition to pharmacological therapy, psychotherapy is an integral component in treating OCD in younger patients. Behavioral and cognitive-behavioral approaches dominate research into OCD psychotherapy, with exposure and response prevention (ERP) being the most commonly employed technique. ERP is clearly effective, but the evidence suggests that it results in a reduction rather than a removal of symptoms in a significant proportion of patients. This caveat notwithstanding, there is good maintenance gain for many patients. Several case reports using ERP also suggest that this treatment modality may be of benefit in the elderly with OCD. A comparative study of cognitive-behavioral therapy with ERP in 11 elderly OCD patients, mean age 68.7 years, compared to 11 younger patients, mean age 30.3 years, was conducted. These investigators found comparable improvement between the elderly group and younger group, with 72 and 63% improvement, respectively. A number of case reports have illustrated the benefits of combined ERP and psychopharmacological therapy in the elderly. ERP may need to be modified for the elderly due to increased medical comorbidity, cognitive deficits, and decreased stamina. For example, an elderly person with hearing deficits might need videotaped or written descriptions of exposure scenes to administer imaginal flooding rather than audiotapes. For those with mild cognitive impairments, written reminders to resist rituals can be strategically placed in the patient's environment to help with adherence to the response prevention protocol. Pacing treatment may be necessary to prevent some patients from becoming overwhelmed.

Most treatment outcome studies that have examined symptom subtypes have found that compulsive hoarding symptoms are particularly resistant to pharmacological or standard ERP interventions. More recently, this issue has been addressed by integrating motivational enhancement, organizational skills training, and cognitive and ERP techniques. Outcome data in the elderly are limited to a case report of successful treatment of an elderly woman using this approach.

Summary

OCD is more common than previously thought, with prevalence rates across studies in older adults ranging from 0.1 to 4.3%. Disease onset often occurs in young adulthood and its course lasts into old age. Prevalence studies suggest that, unlike in younger adults, the rates in the elderly may be somewhat higher in women than men. Compulsive hoarding is a problem that brings the elderly to the attention of the authorities. What limited data exist suggest few differences in the clinical features, comorbidity, and treatment options of OCD between elderly and younger patients.

See also: Anxiety Disorders; Cognitive-Behavioral Interventions; Dementia; Dementia: Alzheimer's; Depression.

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Organizations On Aging

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Glossary

Advocacy – Urging society to attend to and act on the needs of elders. Elders can act as their own spokespersons, or others, such as service providers (the 'aging enterprise'), can speak and act on their behalf.

Age Consciousness – Identification of oneself with others on the basis of chronological age, as opposed to other kinds of group identification such as race, gender, or religion.

Coalition – An alliance, often temporary, of age-based groups with each other (the 'aging coalition') or with non-age-based groups sharing similar concerns about a variety of issues, such as long-term care, mental health, home modification, or transportation.

Interest Groups – Organizations that seek collective benefits from policy makers through grass roots mobilization and lobbying. Participants (or 'players') in a complex political system, they are based on mass membership or private philanthropies or made up of professionals, business or industry groupings, or consumer subgroups.

Politics of Aging – The process by which aging groups make demands on the policy system by bargaining, persuading, competing, or allying with other interest groups and/or bureaucrats, thereby creating a policy subsystem, and sometimes threatening the re-election prospects of elected officials.

Public Policy for the Aged – Policies that are enacted by governments at all levels to benefit older persons, often with chronological age as the determining factor. They include Social Security, Medicare, state tax preferences, and local zoning benefiting older persons.

Social Movements – Grass roots mobilization of like-minded individuals, often by a charismatic leader, to voice grievances. While characteristically disorganized initially, they can evolve into interest groups. Examples include civil rights and women's and senior groups.

Introduction

Organizations on aging are stable, non-profit collective entities that are distinguished by their advocacy for the betterment of older adults in society through research, education, and service. Most are 501(c)(3) organizations and are tax exempt. They are not necessarily identifiable by the words 'age' or 'aging' in their names; the majority, however, do include those terms or related ones, such as retired, older, or senior. Several types exist. Mass membership groups composed of older adults are often driven by age consciousness. They and other age-based entities, composed of researchers, consumers, practitioners, and businesses providing services to the aged, focus on ensuring that public policies and private activities benefit the elderly.

Social Movement and Interest Group Theory

Both social movement and interest group theory have been used to explain the rise and greater visibility of

organizations on aging. Social movements involve collective actions to aggregate interests on a broad scale and are often characterized by three stages. The first, or developmental, stage consists of erratic expressions of grievances by individuals who feel left out or left behind by the larger society in terms of economic or political benefits. These disgruntled feelings are often catalyzed by a populist leader into an ad hoc organization that focuses heavily on political solutions to perceived wrongs. The second, or institutional, phase consists of a large membership base and a stable organization with economic and political resources, division of labor and hierarchy, and connections with government officials. United States history is replete with such social movements from the mid-nineteenth century on, some of which have evolved into political parties or interest groups. A third stage may include decline and death of the movement, either because the cause espoused is no longer relevant or the organization loses its clout or even becomes dysfunctional due to leadership, finances, and other internal problems.

Interest group or pluralist theory posits that politics is characterized by dispersed power, competition, and bargaining over specific goals by multiple groups or factions, and the responsiveness of decision makers to a wide range of societal interests and the voting public. Interest groups operate within a complex milieu of macroeconomic development, political parties, government officials, and policy professionals, as well as prevailing values and public attitudes toward the role of government or other societal institutions.

A Brief History of Organizations on Aging

The history of organizations on aging can be divided into three periods: the 1920s–1950s, an incubation stage; the 1960s–1970s, a proliferation period; and the 1980s–1990s, a specialization and consolidation era. These groups grew out of the state-level movement for old-age pensions, initially led by non-aging groups, such as the Fraternal Order of the Eagles and the Ham and Eggs movement. Between 1923 and 1933, 25 states enacted old-age assistance laws.

Incubation

The first age-based group was started by Francis Townsend in California, a hotbed of old-age politics. He had a plan for a national pension of $200 per month – a substantial sum in those days – to be paid to everyone age 60 and over, financed by a national sales tax. This plan led to a national movement, by early 1935, of more than 3000 clubs nationwide. After Social Security passed later that same year, the organization's membership and support began to decline because the new law met some of the needs identified in Townsend's mass appeal to elders who were especially hard hit by the Depression. Even so, the Townsend movement went on to sponsor congressional candidates in 1938; 147 Townsend endorsees were elected. After that peak, the movement subsided and disappeared, partly due to problems with leadership and the handling of funds.

The enactment of Social Security initiated a direct relationship between the federal government and the elderly, based on social insurance against the economic risks of old age as a matter of right. Despite the new law, older persons were still at a disadvantage. Still, no other mass membership organization came into being; instead, two professional organizations composed of practitioners and academics were created: the American Geriatrics Society (AGS) in 1942 and the Gerontological Society of America (GSA) in 1948. Two other United States organizations on aging were created in the late 1940s. One was a mass membership entity, the National Retired Teachers Association (NRTA), led by Dr. Ethel Percy Andrus, a former high school principal. The NRTA focused on the lack of pensions for public school teachers and their need for benefits such as life insurance that were otherwise difficult to obtain. The other was the National Association of Retired Federal Employees, whose agenda emphasized pensions for federal civilian retirees. Advocacy by both groups centered on the economic needs of specific employee groups.

The pace of formation of new organizations on aging picked up slightly in the 1950s. The 'new kids on the block' included the National Welfare Assembly; the precursor to the National Council on Aging and the Western Gerontological Society (later to become the American Society on Aging), both composed largely of practitioners; and the American Association of Retired Persons (AARP), a second creation of Dr. Andrus that was destined to become the primary mass membership organization in America. The AARP advocated against age discrimination and in favor of the contributions to be made by the aged to society. International organizations on aging also were initiated during this decade: the Canadian Geriatric Research Society and the International Association of Gerontology, whose membership comprised the growing number of national gerontological organizations, such as the GSA. By the time the turbulent 1960s began, only a handful of organizations on aging existed.

Proliferation

The 1960s and 1970s ushered in a proliferation of interest groups in general, and age-based groups in particular. These decades also generated a 'golden age' in the politics of aging. The Senior Citizens for Kennedy thrust age-related issues into the arena of presidential politics. The 1961 and then the 1971 White House Conference on Aging (WHCoA) provided a forum for discussing the needs of the aged, and new public policies benefiting elders were enacted: Medicare, the Older Americans Act (OAA), Medicaid, and Supplemental Security Income. Although the extent to which age-based groups were primarily responsible for these entitlements is controversial, their ability to work with other established groups, especially labor unions, was an important factor. They also developed age-based coalitions to encompass the different agendas of mass membership organizations (e.g., AARP), professionals (e.g., NCoA), and academics (e.g., GSA) and a wide array of organizations such as the Older Women's League and the National Caucus and Center on Black Aged to represent the concerns of specific subgroups of the elderly, such as women and minorities. In many instances, OAA grants helped fund these new groups. The increase in federal and state programs for elders also gave rise to trade associations (e.g., the American Association of Homes for the Aging) and other entities composed of providers and practitioners (e.g., National Association of State Units on Aging) serving the elderly, dubbed the 'aging enterprise.' This huge increase in organized groups led to the creation of the Leadership Council of Aging Organizations in 1978 to unify the divergent perspectives expressed by the various age-based organizations. Another international umbrella organization, the International Federation on Ageing, was established, with its members drawn primarily from professionals and consumers.

Specialization and Consolidation

In the 1980s and 1990s, the rapid increases in the numbers of programs for the aged slowed markedly, as did growth in the numbers of new major organizations on aging. Instead, these two decades marked a shift toward more specialized organizations in research, education, and practice. New 'splinter' groups that focused on research included the Alliance for Aging Research and the Alzheimer's Association. Other groups represented the wider range of careers in aging, such as professional geriatric care managers, service coordinators in group housing, nursing home and home care administrators, psychologists in long-term care, and assisted living owners and managers.

The late 1980s and 1990s also were accompanied by a political backlash against elders, signaling an end to the easy public policy gains of earlier decades and a need to consolidate those gains. A few new major organizations were created in response to debates over generational equity and emerging threats to Social Security and Medicare. They included the National Committee to Preserve Social Security and Medicare and Generations United, who countered the arguments put forth by the National Association of Senior Citizens (NASC) and Americans for Generational Equity. In addition, the passage and subsequent repeal of the Medicare Catastrophic Care Act (MCCA) revealed the non-monolithic advocacy stances of age-based groups, as did the growing influence of other organizations (e.g., the NASC) that were more attuned to the agenda of the new Republican majority in the House of Representatives. In spite of these changes, national policy makers had come to view older people as a political force in their own right, beyond their high levels of participation in elections.

Current Status and Characteristics

As of 2005 there are more than 1000 age-based groups at the national, state, and local levels advocating for collective benefits for a highly diverse and growing old-age population. In Washington, D.C., many have achieved insider status, especially AARP, the Alzheimer's Association, and Families/USA, which often join forces on issues such as long-term care. The 'gray lobby' commands many resources necessary for access and influence: leadership stability, consistent sources of income, hierarchical structure, expertise in particular areas, geographic dispersion, and skillful professional lobbyists and public relations capabilities. Some organizations on aging have developed technological capacity, beyond websites, to enhance their advocacy activities, such as listservs designed to remind members to contact policy makers within the relatively short time frames during which bills are voted on.

However, with few exceptions (largely due to their tax-exempt status), age-based groups have not created political action committees (PACs) that increasingly affect electoral politics. Additionally, while some aging groups, particularly AARP, continue to exercise substantial influence on crucial legislation (e.g., the enactment of the Medicare Modernization Act), the political climate in Washington, D.C. is overall less welcoming to any new programs for the elderly compared to earlier decades. Furthermore,

most age-based groups lack the financial resources to engage in lawsuits that increasingly affect pensions, retiree health benefits, and other issues affecting the well-being of the elderly. Finally, the majority of these groups have yet to develop the same kind of sophistication and influence at the state level that they have at the national level. (AARP and the Alzheimer's Association are notable exceptions.) With more responsibilities being devolved to the states, this lack of advocacy structure in state capitals can lead to fewer positive outcomes for older persons.

The Future of Organizations on Aging

In the current policy climate of entitlement cutbacks and continued devolution to the states that got underway in the 1990s, organizations on aging will find it more difficult to promote major new programs, such as national social insurance for long-term care. Both employers and the federal government are pursuing policies that place more responsibility on individuals for their retirement years. The 1995 WHCoA resolutions were quite modest in number (50) and content compared to the hundreds of demands for major programs made at earlier conferences, reflecting the realities of today's politics of aging. The 2005 conference also has been restricted to a maximum of 50 resolutions, and it is likely that many of those will be blocking actions designed to maintain existing programs. If, as has been proposed in the past decade, more federal programs are funded through block grants to the states in such areas as housing, health, and long-term care, age-based groups will need to sharpen and organize their lobbying skills at the state and often local levels. This kind of mobilization can be very expensive, especially for small organizations representing subgroups of the elderly. Monitoring the implementation of block grants in 50 states also will require considerable effort.

Organizations on aging, similar to other constituencies that have benefited from national programs, also will continue to be challenged by the more than decade-long shift in party dominance in Congress and many statehouses. The Republican majority in Congress, with its emphasis on less government, has made it more difficult for the dominant age-based groups to exercise the same kind of influence that they have in the past. For example, while the Medicare Modernization Act resulted in a prescription drug benefit, the final outcome was not endorsed by all organizations on aging, and even AARP, despite having played an important role in its enactment, has gone back to the legislative drawing board to try to correct perceived defects in the new program. Conservative organizations on aging that had little influence on the Democrats have found that they continue to have increased access in the policy process since the Republicans became the majority party in Washington, D.C.

Similarly, the strong showing of Republicans in state elections has resulted in party shifts that may lead to increased influence of traditional state interest groups such as business and industry, which are often at odds with the consumer focus of aging advocates. Term limits for state legislators and executives may also result in age-based groups having less clout as legislators become less driven by the need to assuage older voters to get reelected. Term limits may also increase the influence of groups such as the insurance industry that, unlike nearly all aging groups, contribute heavily to political campaigns.

The backlash against the aged at the national level has not fully subsided, with the likely result that age-based groups will increase their coalition-building activities with non-aging groups, as well as other advocates for the elderly, as they have done since the late 1980s. AARP has, in keeping with its membership demographics, focused more on those aged 50 and over (not 65+) and officially changed its name to AARP, since a substantial proportion of its membership is not retired and is composed of persons younger than age 65. Similarly, AARP, Families/USA, and other well-positioned advocate groups with listserv capacity and other major resources are likely to become the most prominent voices among the numerous organizations on aging. This, coupled with disparate levels of interest in globalization and its impacts on the aged and ever-increasing diversity among the older population, opens the possibility of important differences in advocacy techniques and positions taken among organizations on aging, even beyond what has occurred in the past. The ability of age-based groups to forge strong links with other organizations may very well be the key to retaining current programs – recent skirmishing over Social Security reform is a case in point – and to developing new programs at the federal and/or state level. Whatever the future holds for age-based organizations, new programs that benefit only the aged are less likely to happen than in the past.

See also: Health Care and Services; Medicare and Medicaid and Economic Policy of Health Care; Politics of Aging; Social Security.

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Osteoporosis and Aging Related Bone Disorders

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Glossary

Osteoporosis – A systemic skeletal disease characterized by a low bone mass and a microarchitectual deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture (WHO, 2003: 27).

Introduction

Osteoporosis is among the most common health problems facing elders worldwide.

Globally, the elderly are increasing at a dramatic rate with the number of individuals 65 years or older predicted to rise from 431 million in 2000 to 696 million by the year 2020. During this same period of time, the number of persons 75 years and older is expected to rise from 163 to 269 million. Since the incidence of osteoporotic hip fracture increases exponentially with age, this demographic shift could dramatically increase the number of hip fractures, posing a devastating increase in disability and cost for elders worldwide. Faced with other pressing and acute health problems such as tuberculosis, AIDS, and malaria, there is concern that the more innocuous-appearing problem of osteoporosis may be relegated to a low priority in many countries. For these reasons, it is imperative that an algorithm be developed and instituted worldwide to support lifestyle changes and early diagnosis of osteoporosis, in time to avoid fractures if at all possible. But the first and perhaps most difficult challenge that must be addressed is to change the prevailing misperception that osteoporosis and fracture are inevitable conditions of growing old. Toward that purpose, the World Health Organization (WHO), in collaboration with organizations concerned nationally and internationally with bone health, has declared 2002–11 as the Decade of the Bone and Joint, uniting nations throughout the world in the commitment of energy and resources to accelerate progress in bone health and prevention of fractures. Keeping in mind this global context, this article focuses primarily on the incidence of osteoporosis within the United States, noting risk by specific demographic features when that information is available.

Given that osteoporosis and osteoporotic fractures represent the most widespread and devastating bone health problem, this article focuses primarily on osteoporosis, with a subsection on other bone disorders that affect elders. Discussions include information about the prevalence and impact of osteoporosis, pathology (including bone remodeling), factors that place individuals at risk for developing osteoporosis, screening and diagnostic measures, and treatment. Encouraging information is also provided about recent innovative technological developments that may enhance our ability to detect and treat osteoporosis in time to reduce and better manage its unwelcome sequelae. The *2004 Surgeon General's Report on Bone Health and Osteoporosis*, prepared by the US Department of Health and Human Services under the direction of the Office of the Surgeon General, represents the most definitive document available on this

topic, and serves as a primary source of information for this article.

Prevalence

Osteoporosis is defined as a skeletal disease characterized by low bone mass and deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture. Osteopenia refers to a decrease in bone mass below normal, but not low enough to be classified as osteoporosis. The WHO measures prevalence directly by using bone mineral density (BMD) data, and measures incidence indirectly as the number of fractures resulting from the disorder. However, since most data are from developed countries, there is a deficit of standardized criteria on the prevalence of osteoporosis on a multinational basis. Different measurement techniques are used to collect BMD data at varied skeletal sites, on subjects of different age groups, limiting generalizations. In addition, the WHO criteria base the standard BMD scores on the mean scores of young White women, making it difficult to generalize findings to groups other than Caucasian women. In the United States, prevalence of osteoporosis ranges from 3.9% in Caucasian American women who are 50–59 years old, increasing to 47.5% for those older than 80. The National Osteoporosis Foundation (NOF) estimated that 55% of all Americans aged 50 and older in the year 2002 had either osteoporosis or osteopenia (low bone mass). Based on the 2000 census, prevalence estimates increased to 52 million women and men for the year 2010 and to 61 million in 2020. In the United Kingdom, it has been estimated that 23% of women 50 years or older are osteoporotic, with increases proportional to age. The percentages of Swedish women who have osteoporosis range from 7% of women 50–59 years of age to 36% of those 80–89 years. The prevalence of osteoporosis is higher for women in Norway than anywhere else in Europe, and the risk of hip fracture among Norwegians is four times that of Southern Europeans and double that of Americans.

Prevalence varies by gender, race, and ethnic group. Both men and women experience a decline in BMD starting in midlife, with women experiencing more rapid bone loss in the years immediately after menopause. Of the 44 million people in the United States estimated to have osteoporosis in 2002, 32% were men and 68% were women, confirming that osteoporosis is not just a problem among women. Asian and White non-Hispanic women have the lowest bone mineral densities throughout life, and African American women have the highest. Mexican American women have bone densities that are intermediate between the two groups. Limited data suggest that Japanese and Native American women attain a peak BMD that is lower than for White non-Hispanic women.

Virtually all fractures occur in persons 35 years and older, with 80% occurring in women. The highest incidence rates are reported in northern Europe, the northern part of the United States, and among Southeast Asian populations, with the lowest rate from African countries. It is of note that the differences in incidence of hip fractures between countries are greater than differences between gender.

Impact

Osteoporosis is identified as a major public health concern for Americans aged 50 years and older. More than 75% of those affected by osteoporosis are women, and the WHO estimates that up to 70% of women older than 80 years of age have osteoporosis. One in every two women and one in every five men over 50 years of age experience an osteoporotic fracture during their lives, and more women die from the after-effects of osteoporotic fractures than from cancers of the ovaries, cervix, and uterus combined. There are 1.5 million osteoporotic fractures in the United States each year; 20% are hip fractures, 50% are vertebral fractures that lead to height loss, and 30% are at the wrist and other sites. One-fourth (25%) of all postmenopausal women will develop a vertebral deformity, and another 15% will sustain a fractured hip, numbers that could triple by 2040.

Hip fractures are the most severe consequence of osteoporosis and are associated with lengthy hospital admissions, difficulty in performing activities of daily life, nursing home placement, and a high rate of mortality. In 1998, more than 339 000 hip fractures occurred in men and women aged 65 and older in the United States, and the annual worldwide incidence is projected to grow to 2.6 million by 2025 and to 4.5 million by 2050. Virtually all persons in the United States with hip fracture are hospitalized, and 25% of those who sustain hip fractures require long-term nursing home care. Hip fractures account for 140 000 nursing home admissions annually. Spine fractures are considerably less problematic in terms of cost, with only 10% requiring hospitalization and less than 2% being admitted to a nursing home. However, they account for 66 000 physician office visits and at least 45 000 hospital admissions each year.

The economic burden of osteoporosis to society is immense. In the United States, osteoporotic fractures result in more than half a million hospitalizations,

800 000 emergency room visits, more than 2.6 million physician office visits, and the placement of nearly 180 000 individuals into nursing homes. It is estimated that each hip fracture represents approximately $40 000 in total medical costs. The annual direct care costs associated with osteoporotic fractures is estimated to be as high as $18 billion, and indirect costs (i.e., lost productivity for patients and caregivers) add billions of dollars to this amount. Care to White women comprises the majority of these costs, but men and non-White women of all ages account for $1 billion in direct costs of osteoporotic fractures. Due to the late age at which the expenses related to care occur, osteoporosis accounts for 14% of all days spent in nursing homes. Given that 75% of all hip, spine, and distal forearm fractures occur in persons 65 years and older, the direct costs are largely borne by society, in the form of social reimbursement programs. In the United States, Medicare pays approximately one-half of these costs, and Medicaid covers an additional one-fourth of the expense.

But the impact of osteoporosis on the personal lives of the patients and their families is even greater. Nearly one in five persons who sustain a hip fracture end up in a nursing home, and 20% will die before a year has passed. Two-thirds of hip fracture patients never return to their prefracture level of function, and many lose their ability to walk. Reports from the Established Populations for Epidemiologic Studies of the Elderly (EPESE) confirm that 37% lose the ability to dress themselves, 58% lose the ability to move from their chair to standing, and 60% lose the capacity to walk across the room. The sequelae of bone disease can also affect an individual's self-esteem, body image, and mood and may result in other serious psychological consequences. In a survey conducted by the NOF, 89% of the women who had sustained an osteoporotic fracture said they were afraid of breaking another bone, 80% feared losing their independence, 80% feared they would not be able to perform their daily activities, and 68% were afraid that they would have to go to a nursing home if they had another fracture. Approximately half of the individuals who sustain hip fractures never walk independently again, even if they were ambulatory before their fracture.

Pathology

There is general consensus that BMD accounts for 70% of bone strength, is measured as grams of mineral per area, and reflects both peak bone mass and the amount of bone loss. Osteoporosis is not only the result of accelerated bone loss during aging, but it may also develop because of suboptimal bone growth in childhood and adolescence or from the use of certain medications (most notably steroids) for the treatment of other health problems. Bone quality is not well understood, but is thought to result from the bone's micro and macro structure, biochemical composition, distribution and integrity of material components within bone, turnover, and microdamage accumulation. Fracture risk is currently estimated by measuring BMD. The risk of fracture rises sharply as BMD declines. The estimated lifetime risk for wrist, hip, and vertebral fractures is 15%. The majority of these fractures in persons over 50 years of age are a result of osteoporosis, and the hip fracture rate is used to calculate the osteoporosis fracture burden. Since most individuals who have a low density have also lost bone structure, a low T score is usually accurate. However, it should be noted that the BMD only measures bone density and does not assess the quality of the bone structure. Therefore, some individuals with high bone density may sustain fractures, because they have lost bone structure. Conversely, not all persons with low bone density sustain fractures, because they may have retained good bone structure. Prior fracture is one of the most important predictors of future fracture. The risk of hip fracture after a wrist fracture was increased 1.4-fold in US women, 1.5-fold in Swedish women, and 1.8-fold in Danish women. Wrist fracture is an even stronger predictor of hip fracture in men; US men who had a wrist fracture were found to be 2.3 times more likely to sustain a hip fracture, and Swedish men with wrist fracture were 2.8 times more likely to sustain hip fracture.

Bone Remodeling and the Development of Osteoporosis

Although an individual's height and unique bone structure are developed by late adolescence, new bone continuously replaces old bone throughout life in a process referred to as bone remodeling. Bone remodeling helps one's skeleton maintain its structural integrity; it is estimated that approximately 10% of the skeleton is remodeled annually, with most of the adult skeleton being replaced every 10 years. Eighty percent of the skeleton is cortical (compact) bone, which is located predominantly on the outer surfaces of the bone, and 20% is inner trabecular (spongy) tissue, which forms a large part of the vertebrae, proximal femur, and distal radius. If less new bone is formed than the amount of old bone removed, a net loss of bone occurs, and the more fragile bone is more likely to break with less trauma, as is the clinical problem with osteoporosis. It should

also be noted that remodeling bone is inherently weaker, and is therefore more susceptible to fracture. Remodeling occurs in both types of bone, but most (80%) occurs in the trabecular bone. Thus, fractures are more likely to occur in regions of high trabecular area such as the hip, spine, and wrist.

In the complex bone remodeling sequence, bone cells lie quiescent until osteoclasts (bone-resorbing cells) are stimulated to resorb a small volume of bone. While some of the details of the actual remodeling process remain unclear, it is thought that this osteoclast (resorbing) activity is increased by a number of factors, including parathyroid hormone (PTH) and thyroxine, and that it is decreased by estrogen, testosterone, vitamin D, calcium, high phosphorus levels, and sometimes by cytokines from osteoblasts (bone-forming cells). Localized prostaglandins and interleukins may also exert a stimulatory or inhibitory effect on this remodeling process. A low calcium intake stimulates the secretion of PTH, which activates the osteoclasts to release lysosomal enzymes that digest bone matrix, causing the release of calcium and other bone minerals and proteins. After the resorption cavity is formed, a cement line is laid down by macrophage-type mononuclear cells, limiting further resorption on bone in that particular area. The cement line is rich in osteopontin, which may serve to shut off osteoclast (resorption) activity and stimulate osteoblast (rebuilding) activity. A growing number of pharmaceutical modalities have been developed with the goal of reducing bone loss or increasing bone formation to maintain bone health by inhibiting osteoclast action on bone resorption or by allowing formation to continue.

Predictors and Risk Factors

Factors associated with low bone density and/or risk for fracture have been identified in several large prospective studies:

- Female gender
- Advancing age
- Traditionally defined Caucasian and Asian populations
- Estrogen deficiency due to menopause, especially early or surgically induced. Sometimes categorized as a secondary cause
- Low weight and body mass index (i.e., small frame)
- Personal history of fracture after age 50
- Family history of osteoporosis
- Cigarette smoking
- Low lifetime calcium and vitamin D intake
- Inactive lifestyle
- Insufficient exposure to sun (reducing production of vitamin D, which is essential for calcium absorption).

Other suspected predictors of low bone mass, including use of alcohol and caffeine-containing beverages, have proven to be inconsistent in their association with the development of osteoporosis. Higher body mass index, African American heritage, sufficient estrogen levels, and stress-applying exercise are viewed as BMD protective factors, while age, personal or family history of fracture, Asian or Hispanic heritage, smoking, and cortisone use are significant predictors of osteoporosis.

Secondary (modifiable) causes are believed to contribute to 30–60% of osteoporosis in men and more than 50% in perimenopausal women. Among men, hypogonadism, glucocorticoid therapy, and alcoholism are the most common secondary causes. In perimenopausal women, hypoestrogenemia, glucocorticoid therapy, thyroid hormone excess, and anticonvulsant therapy are the most common secondary causes.

- Exogenous glucocorticoid use as a treatment for a coexisting condition (i.e., for treatment for asthma, or in conjunction with transplants) is the most common cause of secondary osteoporosis, and its long-term use is associated with high rate of fracture. Glucocorticoids suppress bone formation and increase bone resorption by affecting local regulatory factors, suppressing collagen synthesis, and inhibiting calcium absorption. An emerging population affected by this risk are persons with organ transplants, who rely on steroid therapy to minimize the risk of rejection.
- Hypogonadism affects osteoblastic cell functioning in both women and men. Production of estrogens maintains bone mass. In women, the timing of menarche and menopause influences the attainment and preservation of peak bone mass, and in men estrogens similarly play an important part in building and maintaining the male skeleton. Androgens are also important regulators of bone metabolism, including cellular effects on bone remodeling. Hypogonadism distinct from postmenopausal status in women and age-related decline in men may be caused by diseases such as hyperprolactemia, hemochromatosis, Klinefelter's syndrome, mumps orchitis, anorexia nervosa, and excessive exercise-induced hypogonadism.
- Hyperthyroidism has detrimental effects on the skeleton, especially in females. Thyroid hormones stimulate bone resorption, decrease calcium intestinal absorption, and increase hypercalciuria,

resulting in a decrease in bone density and an increase in risk of fracture in individuals with a history of thyrotoxicosis.
- Drug therapies associated with reduced bone mass in adults include pharmaceutical preparations that contain aluminum, anticonvulsants (phenobarbital, phenytoin), cytoxic drugs, gonadotropin-releasing hormone agonists, lithium, long-term heparin use, long-acting parenteral progesterone, supraphysiological thyroxin doses, tamoxifen (premenopausal use), and total parenteral nutrition.

Presenting Symptoms and Sequelae

While the skeletal changes in osteoporosis result in significant chronic morbidity and mortality, the changes in bone mass and quality occur without symptoms and are usually not detected until a fracture occurs. Fractures of the proximal femur (hip), vertebrae (spine), and distal forearm (wrist) are the most clinically apparent complications of osteoporosis and may profoundly affect quality of life. Bone loss, in the presence of risk factors and age-related changes such as compromised vision, hearing, proprioception, and balance, may lead to greatly increased risk of fracture due to falls. Vertebral fractures, often called crush fractures, result in the characteristic physical changes often associated with osteoporosis, most notably kyphosis or dowager's hump. This collapsing of the vertebral column onto itself impacts other body systems: gastrointestinal, respiratory, genitourinary, and craniofacial, and produces concomitant morbidity: height loss, abdominal protuberance and fullness, inhibited breathing patterns, back pain, and functional limitations in walking, bending, and reaching.

Diagnosis and Treatment

Guidelines for Screening

Osteoporosis is a silent disease and usually remains asymptomatic until a fracture occurs. It may present as a spontaneous fracture or collapse of a vertebra or as a backache of varying degrees of severity. Height loss is also common. Osteoporotic fractures are preventable; therefore, appropriate diagnostic tools are crucial in the assessment and treatment of osteopenia and osteoporosis. Bone densitometry has made it feasible for health-care providers to diagnose osteoporosis before the first fracture occurs and to reliably predict fracture risk in postmenopausal women, men, those at high risk, and those receiving glucocorticoids. It can also be used as a surrogate marker to determine the effectiveness of therapies and to evaluate those patients that might not respond to osteoporosis therapy. There are several methods currently available to determine bone mass. Currently, dual energy X-ray absorptiometry (DXA) has become the measurement of choice for osteoporosis. The results are reported in T scores and Z scores. The WHO classifies normal bone density as a T score of -1 or above, osteopenia as a T score between -1 and -2.5, and osteoporosis as a T score of -2.5 or below. Less commonly used are Z scores, which classify the type of osteoporosis and may be helpful in identifying those in need of testing for secondary osteoporosis. Z scores of –1.5 and below indicate primary osteoporosis that is age related, and a score of –1.5 and above indicates secondary osteoporosis. Once osteoporosis has been diagnosed, a history is carefully taken and a physical examination is performed to determine the cause.

The National Osteoporosis Foundation and the US Preventive Services Task Force (USPSTF) have established recommendations on screening for osteoporosis (**Table 1**). A number of reliable portable bone scanners have also become available, making low cost detection of low bone density increasingly feasible as a more widespread screening procedure for osteoporosis.

BMD measurements correlate strongly with the load-bearing capacity of the hip and spine, detect osteoporosis before a fracture occurs, predict fracture risk, assess the rate of bone loss with repeated measures, and monitor the effectiveness of treatment

Table 1 Recommendations on screening for osteoporosis

National Osteoporosis Foundation	*US Preventive Services Task Force (USPSTF)*
Bone mineral density testing should be performed on: 1. All women aged 65 and older regardless of risk factors 2. Younger postmenopausal women with one or more risk factors 3. Postmenopausal women who present with fractures (to confirm the diagnosis and determine disease severity)	Screening summary: 1. Women aged 65 and older should be screened routinely for osteoporosis 2. Routine screening should begin at age 60 for women at increased risk for osteoporotic fractures 3. The USPSTF makes no recommendation for or against routine osteoporosis screening in postmenopausal women who are younger than 60 or in women aged 60 to 64 who are not at increased risk for osteoporotic fractures

for osteoporosis. Several different techniques are now available to assess BMD at multiple skeletal sites.

DXA of the hip and spine is presently considered the gold standard in assessing fracture risk. Used to measure BMD of the hip, spine, or wrist, the DXA takes about 10 min to perform with low radiation exposure (one-tenth that of a standard chest X-ray). However, DXA is not universally available for screening for osteoporosis, partly because the equipment is large and expensive and is not portable. Additionally, the National Institutes of Health (NIH) has concluded that the value of universal screening, especially in perimenopausal women, has not yet been supported by compelling evidence. Perhaps for this same reason, the costs are not consistently covered by insurance companies and other third-party reimbursement programs.

Prevention, Risk Management, and Treatment

Calcium and Vitamin D Over a lifetime, inadequate supply of calcium in the diet is thought to play a significant role in the development of osteoporosis. The literature supports the need to develop healthy behaviors early in life to build and maintain strong bones. This includes consuming a healthy diet, maintaining normal weight, and exercising regularly. Calcium is the specific nutrient required for achieving peak bone mass and for preventing and treating osteoporosis. Calcium absorption is incomplete, usually about 10–12%, and vitamin D is needed for the best possible absorption. Vitamin D is not a normal constituent of most foods but is usually endogenously produced by a photosynthetic reaction. Few foods contain or are fortified with vitamin D; more than 90% of the required vitamin D comes from sunlight exposure. Short (15 min) exposure of hands, face, or arms and legs to sunlight, before the application of sunscreen, may produce an adequate amount of vitamin D. Adequate calcium and vitamin D intake provided through eating a diet high in low-fat dairy products and calcium-fortified foods is preferred to supplements, since other beneficial nutrients including phosphorus and magnesium are also found in these foods. Supplemental calcium and vitamin D is recommended for individuals who are unable to consume a sufficient amount of foods rich in calcium. The Institute of Medicine of the National Academy of Sciences recommends a calcium intake for healthy individuals over 50 years of 1200 mg/day and a vitamin D intake of 400–800 IU/day. However, the NOF advises all individuals to obtain a dietary intake of calcium of at least 1200 mg/day, including supplements if necessary. A single dose of calcium should not exceed 500–600 mg of elemental calcium per dose to ensure absorption. Individuals with established osteoporosis, pregnant or nursing women, those using glucocorticoids, and those over 65 require 1500 mg/day of calcium with 600–800 mg/day of vitamin D. Women who lack adequate sunlight exposure should receive up to 800 IU/day of vitamin D. The recommendations of the Institute of Medicine of the National Academy of Sciences for calcium and vitamin D intake are listed in **Table 2**.

Table 2 Dietary calcium and vitamin D recommendations

Age	*Calcium (mg/day)*	*Calcium for women who are pregnant or lactating (mg/day)*	*Vitamin D*
4–8	800		200 IU (5 μg)
9–18	1300	1300	200 IU (5 μg)
19–50	1000	1000	200 IU (5 μg)
51–70	1200		400 IU (10 μg)
>70	1200		600 IU (15 μg)

From the Institute of Medicine of the National Academy of Sciences (1997).

Hormone Therapy Estrogen is essential in the maintenance of bone mass in women, and it has been well established that after menopause, some women experience rapid bone loss due to increased bone resorption. Specifically, there is an accelerated period of bone loss during the early menopausal years during which women may lose bone mass at the rate of up to 3–5% per year for approximately 5–7 years. In 1984 the NIH Consensus Conference on osteoporosis stated that estrogens were the most effective way to prevent bone loss in postmenopausal women. The main estrogen in use was Premarin (conjugated equine estrogen [CEE]); a progestin was added to prevent endometrial hyperplasia in women with an intact uterus. Estrogen and progestin use increased and was effective in preventing osteoporosis.

However, in 2002 the Women's Health Initiative (WHI) reported greater potential harm than benefit from the use of CEE plus a progestin. This report changed the way that health-care providers managed the treatment of postmenopausal women in terms of osteoporosis prevention. The WHI study was a large, well-publicized, placebo-controlled randomized trial of healthy postmenopausal women ages 50 to 79 who received daily oral CEE/medroxyprogesterone (E + P), Prempro (0.625 mg/2.5 mg). The positive results showed an overall 24% reduction in all fractures after 5.6 years of follow-up and a 33% decrease in hip fractures in women receiving E + P(B). However, the WHI findings also demonstrated that Prempro increased the risk of breast cancer, myocardial

Table 3 FDA-approved drugs for the prevention of osteoporosis in postmenopausal women

Hormones	*Dosage*
Activilla (estradiol/norethindrone acetate)	1 mg/0.5 mg qd
Femhrt (norethindrone acetate/ethinyl estradiol)	0.5 mg/2.5 μg, prevention: 1 mg/5 μg qd
Ortho-Prefest (estradiol/norgestimate)	1 mg/d for 3 days, then 1 mg/0.09 mg/qd for 3 days repeated
Premphase (conjugated equine estrogens/ medroxyprogesterone [MPA])	0.625 mg/day 1–14, then 0.625 mg/mg/day 15–28 0.3 mg/1.5 mg/day
Prempro (conjugated equine estrogens/MPA)	0.3 mg/1.5 mg/day, 0.45 mg/1.5 mg/day, 0.625 mg/2.5 mg/day Prevention: 0.3 mg/1.5 mg/day
Estrace (estradiol)	0.5 mg, 1 mg, 2 mg
Ogen (estrone sodium as estropipate)	0.625 mg, 1.25 mg, 2.5 mg Prevention: 0.625 mg qd
Ortho-est (estropipate)	0.75 mg, 1.5 mg qd Prevention: 0.75 mg
Premarin (conjugated equine estrogens)	0.3 mg, 0,45 mg, 0.625, 0.9 mg, 1.25 mg, 2.5 mg Prevention: 0.3 mg/day
Alora (transdermal) (estradiol)	0.025 mg/day, 0.05 mg/day, 0.075 mg/day, 0.1 mg/day Prevention: 0.05 mg/day patch applied 2/week
Estroderm (transdermal) (estrodiol)	0.05 mg/day, 0.1 mg/day Prevention: 0.05 mg/day patch applied 2/week
Vivelle (transdermal) (estradiol)	0.05 mg/day, 0.1 mg Prevention: 0.025 mg/day patch applied 2/week
Vivelle Dot (transdermal) (estradiol)	0.025 mg/day, 0.0375 mg/day, 0.05 mg/day, 0.075 mg/day, 0.1 mg/day Prevention: 0.025 mg/day patch applied 2/week
Climar (patch) (estradiol)	0.025 mg/day, 0.0375 mg/day, 0.05 mg/day, 0.06 mg/day, 0.075 mg/day, 0.1 mg/day Prevention: 0.025 mg/day patch applied 1/week
Menostar (transdermal) (estradiol)	0.014 mg/day patch applied 1/week

infarction, stroke, pulmonary emboli, and deep vein phlebitis. As a result of this report, many health-care providers promptly discontinued hormone therapy, fearing the increased risk of these serious side effects. In addition, women themselves stopped the use of hormone therapy after hearing about the report, which was widely publicized. As a result, there has been a precipitous decrease in estrogen and progesterone use and a critical re-examination of the use of menopausal hormone therapy. The report has also fostered an increased interest in alternative methods to managing menopausal symptoms, and the use of bioidentical hormones and herbal therapies has ensued. In addition, the Food and Drug Administration (FDA) guidelines concerning treatment to control menopausal symptoms and osteoporosis prevention have resulted in a variety of estrogen and progesterone formulations, doses, and routes of administration, affording various options for women who seek conventional therapy (**Table 3**).

Phytoestrogens, plant-derived natural estrogens, have mild estrogen-like effects in epidemiological and cell line research, but no reduction in fracture incidence has been demonstrated. Human intervention studies to assess the clinical effects of phytoestrogens are needed.

Bisphosphonates (FDA Approved) Bisphosphonates are non-hormonal drugs that decrease bone resorption. Currently there are three bisphosphonates approved by the FDA for the prevention and treatment of osteoporosis. Alendronate (Fosamax) and risedronate (Actonel), in randomized controlled trials, demonstrated an increase in BMD and decrease in the risk of vertebral and non-vertebral fractures in both early postmenopausal women and those with established osteoporosis. The dosing for alendronate is 5 mg daily or 35 mg weekly (prevention), 10 mg daily or 70 mg weekly (treatment), and it is 5 mg daily or 35 mg weekly for risedronate. They must be taken with 8 oz of water 30 min after an overnight fast. In addition, the patient must remain upright for 30 min after ingesting the pill to reduce esophageal irritation (**Table 4**).

Ibandronate (Boniva) is the newest bisphosphonate that can be dosed daily or monthly. It is dosed at 2.5 mg daily or 150 mg once monthly on an empty stomach with 8 oz of water 60 min before other medications, fluids, or food. Again, the patient must be able to remain upright for 60 min after taking the pill. Ibandronate has been shown to decrease vertebral fractures in women with osteoporosis and a history of previous vertebral fracture. There is no

Table 4 FDA-approved non-hormonal drugs for the treatment and prevention of osteoporosis in postmenopausal women

Bisphosphonates
Fosamax (alendronate): 5 mg, 10 mg, 35 mg, 40 mg, 70 mg, 70 mg/75 ml (oral solution); prevention: 5 mg/day or 35 mg/week; treatment: 10 mg/day or 70 mg/week
Actonel (risedronate): 5 mg, 30 mg, 35 mg; prevention and treatment: 5 mg/day or 35 mg/week
Boniva (ibandronate): prevention and treatment: 2.5 mg/day or 150 mg/month
Boniva (ibandronate sodium): treatment: 3 mg quarterly IV
Selective estrogen receptor modulators (SERMS)
Evesta (raloxifene): prevention and treatment: 60 mg/day
Calcitonin
Miacalcin nasal spray (salmon calcitonin): treatment: 200 IU intranasal spray, one spray in nostril daily (alternate nostrils)
Miacalcin injection (salmon calcitonin): treatment: 100 IU SC or IM q other day
Fortical nasal spray (salmon calcitonin): treatment: 200 IU intranasal spray
Parathyroid hormone
Forteo (teriparatide): treatment: 20 μg SC/day

evidence showing that it reduces hip fracture or other non-vertebral fracture, nor that it reduces fracture in women without previous fracture. An intravenous formulation, ibandronate sodium, that is administered quarterly was recently approved by the FDA for the treatment of postmenopausal osteoporosis. Boniva injection is administered over 15–30 s and provides an alternative for patients who are unable to tolerate oral bisphosphonates or who are unable to remain upright for 30 to 60 min (**Table 4**).

Other Bisphosphonates (Non FDA Approved) Other bisphosphonates, while not FDA approved to treat postmenopausal osteoporosis, are available off-label for patients who are unable to tolerate approved preparations. One preparation is zoledronic acid (Zometa), an intravenous (IV) bisphosphonate (4 mg once yearly or less) FDA approved to treat hypercalcemia of malignancy. Generally side effects are mild and of short duration. Current thinking includes the future use of zoledronic acid to treat postmenopausal osteoporosis in patients unable to tolerate oral preparations. Another antihypercalcemia preparation is pamidronate (Aredia), given IV for hypercalcemia, Paget's disease of bone, and bone metastasis. Etidronate (Didronel) is an oral preparation used to treat hypercalcemia and Paget's disease.

Calcitonin Salmon calcitonin (Miacalcin), Calcimar, or Fortical is a peptide hormone approved by the FDA for treatment of osteoporosis in women who are 5 years postmenopausal; it is not approved for prevention. Most commonly it is administered intranasally once daily (200 IU); it may also have an analgesic effect.

This preparation is also available for subcutaneous injection. Calcitonin increases BMD at the lumbar spine and decreases vertebral fracture risk, but it has not been shown to alter non-vertebral fracture rates. It is generally well tolerated, and side effects include rhinitis and, rarely, epistaxis (**Table 4**).

Selective Estrogen Receptor Modulators (SERMS) Raloxifene (Evista) and tamoxifen (Nolvadex), similar in magnitude to that of estrogen, are a class of drugs called selective estrogen receptor modulators (SERMS). Raloxifene exerts estrogen-like effects on bone and blocks estrogen effects on breast and uterus. Raloxifene's use in osteoporosis prevention and treatment is recommended in women >60 years of age at a dose of 60 mg daily. Raloxifene, however, increases the risk of deep vein thrombosis, pulmonary emboli, leg cramps, and hot flashes. Tamoxifen, used in breast cancer therapy, also positively affects bone mass in postmenopausal women (**Table 4**).

Parathyroid Hormone Parathyroid hormone is an anabolic agent that increases bone density by stimulating bone formation. Terparatide (Forteo), the 1-34 sequence of PTH, is approved by the FDA for the treatment of osteoporosis for up to a period of 2 years in postmenopausal women and men at high risk for fractures. The drug is administered by subcutaneous injection of 20 μg daily. Headaches, dizziness, nausea, and leg cramps are adverse effects experienced by some patients. An increase in the incidence of osteosclerosis and osteoscaroma has been observed in rats receiving high doses. This has not been the case in humans receiving therapeutic doses for approximately 3 years (**Table 4**).

Strontium Ranelate Strontium ranelate 2 g/day is a new, well-tolerated oral anabolic agent to treat osteoporosis in postmenopausal women. Originally used in the 1950s to treat osteoporosis, strontium fell out of favor due to a concern regarding mineralization defects. Inappropriate dosing and dietary calcium deficiency may have caused these defects. However, later studies of strontium on bone tissue cultures demonstrated an increased bone formation. This promising research led to renewed interest in the potential application of strontium in the treatment of osteoporosis. Recent studies demonstrate its effectiveness in reducing vertebral fractures in women. Data support the use of strontium ranelate in preventing both vertebral and non-vertebral fractures.

However, strontium ranelate is not FDA approved for the treatment or prevention of osteoporosis at this time.

Overlooked and Emerging Modalities

There exist two useful concepts that are not new, but that have been generally unattended in the search for ways to detect the presence of osteoporosis and prevent hip fracture. Recent studies have confirmed the importance of height loss of more than 1 inch as a reliable indicator of osteoporosis. Yet health-care providers are much more likely to measure weight and blood pressure than they are to measure height. While it is not a new indicator, accurate height measurement is a low-cost marker that merits serious reconsideration for its importance in osteoporosis screening. Likewise, padded hip protectors have shown some promise for decreasing fracture during falls in elderly populations and should be revisited for their value in fracture prevention in persons with severe osteoporosis.

A number of pharmaceutical preparations for treating osteoporosis are in the research phase and are becoming available for treatment. Likewise, community awareness, screening, and education programs are beginning to have an impact in teaching women and their primary care providers about the importance of early diagnosis of osteoporosis and the timely institution of treatment. But for best results, the education and awareness need to be directed toward the young girls and boys who are presently building their peak bone mass, for it is only through their generation and following generations that the problem of osteoporosis can be solved. Osteoporosis is a lifelong condition that manifests itself in old age, and the best treatment is to engage in healthy lifestyles from childhood on, to prevent or reduce bone loss.

Finally, there are a growing number of innovative, non-pharmaceutical biomedical devices under study that hold potential for helping to reduce bone loss and stimulate bone growth non-pharmaceutically. Perhaps the best known such innovation is a vibrating platform device that resembles a laptop computer that delivers a high-frequency, low-magnitude (30 Hz) mechanical signal (perceived as a gentle vibration) to the femur and spine of the standing human. It is thought by its developers to have the capacity to boost bone mass by increasing lower limb circulation of the individual as they stand on the device. Safety of the device has been demonstrated in a 6-month study of children with disabling conditions and in a 1-year randomized clinical trial (opposite a placebo device) in postmenopausal women, with no adverse effects reported. In animal models, the intervention has been shown to inhibit disuse osteopenia. The instrument has also been tested in US Army recruits, and NASA is presently testing the device with astronauts, who are known to lose bone mass while in the weightless environment of space. The treatment is currently being tested using a daily 10-min intervention.

Other Bone Diseases Associated with Aging

Paget's disease is the most common bone disease after osteoporosis. It is a progressive and sometimes crippling disorder of bone remodeling that can affect any bone, but most often involves the spine, pelvis, legs, or skull. Persons with this condition experience an increase in bone loss at the affected site, due to excess numbers of overactive osteoclasts. Bone formation increases to compensate for the loss, but the resulting bone becomes enlarged and is associated with increased formation of blood vessels and connective tissue in the bone marrow, leading to deformity or susceptibility to fracture. The disease can be transmitted across generations, and 15–40% of those affected have an affected relative. However, some studies have suggested that Paget's disease may result from a slow virus infection with measles. If diagnosed early, it can be treated, but it often goes undiagnosed until later in life, when there is pain and thickening or bowing of the affected body part.

Osteomalacia (the adult equivalent of rickets) is a condition in which calcium phosphate is not deposited in the bones correctly. In adults, the condition can lead to fractures in weight-bearing bones such as the pelvis, hip, and feet. Many patients experience bone pain, and some complain of severe muscle weakness. It is a relatively uncommon disease in the United States, since it can usually be prevented with the adequate administration of vitamin D. Osteomalacia can also be caused by disorders that cause loss of phosphorus from the body, and it is sometimes inherited as a mutation of the gene that produces the enzyme necessary to the production of vitamin D. Patients with chronic renal disease are at risk for developing osteomalacia and other bone disorders.

There are also a large number of genetic and developmental disorders of the bone, including a group of usually inherited disorders referred to as osteogenesis imperfecta (OI). The defects associated with this group of diseases interfere with the production of type I collagen (the underlying protein structure of the bone), resulting in low bone mass

leading to recurrent fractures and possible skeletal deformity. Those with type I or type IV, the mildest forms of the disease, may have relatively few fractures, mild to moderate bone deformity, and sometimes dental problems and hearing loss. They may also develop a distinctive blue, purple, or gray discoloration in the whites of their eyes. A more severe form of the disorder (type III) results in more frequent fractures, short stature, hearing loss, and dental problems. Individuals who have the most severe form (type II) typically have numerous fractures and severe deformity, leading to early death. Another group of developmental bone disorders known as oseopetroses causes an increase in bone mass resulting from a genetic defect that impairs the ability of osteoclasts to resorb bone, leading to excessive bone accumulation. Although dense in appearance, the bone fractures easily. In addition, the expanded bone compresses various nerves, causing neurological symptoms such as deafness or blindness. Individuals with this disorder may also suffer from anemia, as blood-forming cells in the bone marrow are crowded out by the excess bone. Two types have been identified in humans, one that is relatively asymptomatic, and another that is usually present at birth and fatal in infancy or early childhood.

One of the most common acquired skeletal disorders is tumor of the bone. Bone tumors may originate in the bone (known as primary tumors) but more commonly result from the seeding of bone by tumors outside the skeleton (metastatic tumors). Primary tumors can be benign (non-cancerous) or malignant (cancerous). Osteochondroma is the most common benign bone tumor, and osteosarcoma and Ewing's sarcoma are the most common malignant bone tumors. Metastatic tumors often result from breast or prostate cancer that has spread to the bone. Bone destruction also occurs with multiple myeloma, which is malignancy of the plasma cells that produce antibodies and cytokines that stimulate osteoclasts and inhibit osteoblasts. Bone-resorbing cytokines are also produced in acute and chronic leukemia, Burkitt's lymphoma, and non-Hodgkins's lymphoma. Other infiltrative processes that affect bone include infections and marrow fibrosis (myelofibrosis).

Finally, the prevalence of oral bone loss is a significant problem among adult populations worldwide. Oral bone, like the rest of the skeleton, comprises both trabecular and cortical bone and undergoes formation and resorption throughout the life span. When oral bone loss exceeds gain, it can cause a loss of tooth-anchoring support or diminish the remaining ridge in those areas where partial or complete tooth loss has occurred. Oral bone loss with resulting tooth loss is associated with estrogen deficiency and osteoporosis and may create the need for periodontal and prosthetic procedures. Oral examination, including radiologic findings, may assist in the diagnosis of extra-oral bone loss.

Summary

Osteoporosis is a devastating public health problem that affects all strata of the global community. The good news is that healthy women and men 50–65 years of age still have time to engage in osteoporosis-preventing behaviors to reduce bone loss and eventual height loss. Concerted effort must be directed toward community education and the development of new treatment modalities to rid towns and communities worldwide of the ravages of osteoporosis, as our predecessors spared modern society from the devastation of polio, smallpox, and rickets. Though less common than osteoporosis, there are also a number of other bone disorders that create serious problems for older adults. It is important that additional research be conducted to find effective treatment measures and that both professionals and the general public be better informed about bone health.

See also: Body: Composition, Weight, Height, and Build; Diet and Nutrition; Falls; Menopause.

Further Reading

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Oxidative Damage

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Glossary

Enzymatic Antioxidant Defense System – Enzymatic antioxidants (antioxidative enzymes) that provide protection against oxidative damage to biological molecules.

Free Radicals and Reactive Oxygen Species – Any chemical species that contains one or more unpaired electrons in the outer atomic or molecular orbitals. Free radicals are normal metabolites and are usually very reactive. Biologically the most important are carbon-centered radicals, produced during lipid peroxidation; sulfur-centered thiyl radicals; nitrogen-centered radicals; and, in particular, oxygen-centered radicals. The terms free radical, oxygen free radical, and reactive oxygen species (ROS) are often employed in biological and medical publications as synonyms. ROS also include the non-radical species H_2O_2 and singlet oxygen, which can be produced through radical reactions and/or can produce free radicals, thereby contributing to oxidative stress. Thus, ROS includes radical and non-radical species. They are usually lumped together because of the increased reactivity of ROS with biomolecules, even if they are non-radical species. Also, free radicals of biological importance include reactive nitrogen species such as nitric oxide that is a free radical synthesized by a family of enzymes called nitric oxide synthases.

Free Radical Theory of Aging – Initially proposed by Denham Harman in 1954, this theory suggests that free radical-inducing and/or -producing biochemical reactions can damage the tissue's major molecular components and that the damage is a cause of aging and is involved in the pathogenesis of many aging-related common chronic diseases.

Lipid Peroxidation – A series of free radical reactions, which usually are initiated in membranes from the interaction of ROS with polyunsaturated fatty acids and which can result in a chain reaction producing aldehydes and hydroperoxides.

Oxidative Damage or Oxidative Injury – Uncontrolled reactions of ROS with the prime targets being bases in DNA, amino acids in proteins, and unsaturated lipids in cell membranes.

Introduction

A variety of reactive oxygen species (ROS) are produced during normal metabolism. They can react with proteins, DNA, and other biomacromolecules, either directly or through a chain of free radical

reactions, which usually are initiated in the membranes by lipid peroxidation. Oxidative damage to biomolecules is limited by antioxidant defenses. But the defenses are not 100% effective. A small percentage of ROS such as superoxide radical and H_2O_2 have been found to escape before contact with deactivating enzymes. Additionally, certain levels of these reactive species are necessary for normal cellular function. Kinetically, ROS can escape from normal cellular metabolic pathways, particularly if present in nonphysiological amounts. Thus, ROS can induce various alterations, including difficult to repair damage to oxidizable biomolecules. These include key molecules, such as tumor suppressor genes, mitochondrial DNA, transcription factors, and DNA repair enzymes. Dysfunction of these molecules may be involved in the pathogenesis of senescence and some of the common chronic diseases.

Chemical and Biochemical Aspects

Important Sources and Mediators of Oxidative Damage

There are endogenous and external sources of 'natural' oxygen free radicals and other ROS. Thus, under normal conditions endogenous ROS are generated in living cells as a by-product of normal metabolism and during cellular/physiological signaling and in connection with inflammatory responses. Specifically, the established endogenous sources of superoxide anion radical and hydrogen peroxide include the mitochondrial electron transport chain, endoplasmic reticulum (microsomal electron transport chain) peroxisomes, nuclear and plasma membranes, and phagocytic cells. Cigarette smoke, sunlight, and dietary factors such as certain metals and substances that oxidize glutathione are among the main exogenous sources of ROS production in the human body. The contribution of each of the ROS-producing cell compartments (cytosol, mitochondria, microsomes, and peroxisomes) to a total 'ROS load' is dependent on the cell type.

Until the beginning of the 1990s, it was generally believed that only phagocytes can generate ROS through events catalyzed by a membrane-associated respiratory NADPH oxidase. But NADPH oxidase-like enzymes, which can be activated by growth factors and which produce $^{\bullet}O_2^-$, have been found in many other cells. Another important source of free radicals is the metabolism of L-arginine, which can result in the production of the free radical nitric oxide, $NO^{\bullet}$.

Biologically relevant production of ROS in human skin by ultraviolet A is well documented. However, some of the biological effects of the sun's UVB (wavelength component 290–320 nm) have been connected with the enhanced generation of ROS. Although the exact source of ROS produced by UVB has not been clearly revealed, it has been demonstrated using human keratinocytes that NADPH oxidase and cyclooxygenase mediate the UVB-induced generation of ROS. This observation reveals that an external 'natural' inducer of ROS produces them in exposed human cells through activation of an endogenous source of ROS, such as NADPH oxidase.

There are three main types of radical reactions *in vivo*: (1) radical addition reactions, (2) electron transfer reactions, and (3) atom abstraction reactions. The chemical reactivity of the superoxide radical is less than the hydroxyl radical. The half-life of the superoxide radical ranges from 0.4 μs to 1 ms. For comparison, the half-life of the hydroxyl radical is 0.3 ns.

Hydrogen peroxide is a weak oxidizing agent and is the most stable intermediate of oxygen's reduction products. However, H_2O_2 can oxidize sulfhydryl groups of enzymes and other proteins such as transcription factors. The effects of very low concentrations of H_2O_2 and $^{\bullet}O_2^-$ are potentiated in the presence of transition metal ions, because extremely reactive hydroxyl radicals, $^{\bullet}OH$, are generated from H_2O_2 by means of transition metal ion-catalyzed reactions called the Fe-catalyzed Haber-Weiss reaction or the Fenton reaction.

Catalysts of $^{\bullet}OH$ radical production can be bound to proteins and membrane lipids and can initiate site-specific protein oxidation and lipid peroxidation if H_2O_2 is formed and/or transported to these sites.

Singlet oxygen is an electronically excited form of oxygen and is a strongly electrophilic molecule produced in tissue as a result of dismutation of superoxide radical. In the skin, singlet oxygen is additionally produced as a result of various photochemical reactions. Nevertheless, the biological role of the production of this 'neglected' ROS under normal conditions or during accelerated aging remains unclear. Singlet oxygen, in addition to the hydroxyl radical, can attack DNA directly. Also, singlet oxygen can damage various enzymes through amino acid modification and may lead to oxidative damage in membranes and blood plasma because it has high reactivity with double bonds in unsaturated fatty acids.

Primary Molecular Defense Mechanisms against Oxidative Damage

Enzymatic Antioxidants Certain enzymes and many small water-soluble and lipid-soluble molecules can

intercept and destroy free radicals and other ROS. Important components of cellular enzymatic protection include catalase, superoxide dismutase (Mn, Cu/Zn, extracellular), glutathione peroxidase, glutathione reductase, glutathione S-transferase, glucose-6-phosphate dehydrogenase, and thioredoxin reductase.

Non-enzymatic Antioxidant Proteins and Low-Molecular-Weight Antioxidants There exist proteins that are not traditionally considered as antioxidants but that have important antioxidant functions. Among them are metallothioneins, low-molecular-weight sulfhydryl-rich Zn/Cu proteins, which are natural scavengers of superoxide and hydroxyl radicals. Important non-enzymatic macromolecular antioxidant defense mechanisms include metal binding proteins such as ferritin and ceruloplasmin, which remove iron and copper ions, respectively. These ions can catalyze the production of $^{\bullet}OH$ and other ROS such as alkoxyradicals.

The antioxidant proteins are supplemented by a number of low-molecular-weight molecules that protect against oxidative damage in tissue. These include (1) endogenous antioxidants, such as reduced glutathione, cysteine, and some other sulfhydryl-containing molecules; ubiquinol 10 in reduced state; bilirubin; uric acid; and lipoic acid in reduced state; and (2) essential antioxidants, vitamin C (ascorbic acid), the principal and terminal scavenger of radicals in the aqueous phase; vitamin E, the principal chain-breaking antioxidant in membranes; vitamin A (retinol), a peroxy radical and thiyl radical scavenger; beta carotene, a precursor to vitamin A and a singlet oxygen quencher; and lycopene, the non-vitamin precursor carotenoid with extremely high singlet oxygen-quenching activity.

Among water-soluble scavengers of free radicals, reduced glutathione (GSH) is one of the most abundant biological antioxidants that function to maintain redox homeostasis *in vivo*. Reduced GSH can scavenge various free radicals. Vitamin C also scavenges various oxy radicals, including thiyl radicals.

Repair of Oxidative Damage One of the most prevalent and best-studied oxidative damage products in DNA is 7,8-dihydro-8-oxo-2′-deoxyguanosine (8-oxodG) (or its base form, 8-oxoguanin [8-oxoG]). This DNA damage is repaired through two pathways. The major pathway, base excision repair (BER), consists of removing the oxidized guanine, while some mammalian cells utilize another pathway, the nucleotide excision repair (NER) pathway. Oxidative damage to DNA, specifically 8-oxoG, may be one of the molecular determinants of aging and may also be involved in the pathogenesis of a number of chronic diseases associated with aging.

Base excision repair is performed by (1) a specific DNA glycosylase that recognizes and removes this damage, resulting in an abasic site; (2) an apurinic-apyrimidinic endonuclease that cleaves the phosphodiester backbone; (3) DNA polymerase, which fills the nucleotide gap, and (4) DNA ligase, which seals it.

Oxidized DNA base repair primarily occurs by this base excision repair pathway, which is important to know in order to properly interpret the results of measurements of 8-oxo deoxyguanosine in human and rodent urine. This nucleoside is primarily excised through the NER pathway, while the glycosylase removes the base but not the nucleoside.

In vivo Measurement of Free Radicals and Markers of Oxidative Stress

An increase in the concentration of free radicals, measured using electron spin resonance (ESR) spectroscopy, can reflect the degree of oxidative stress. An *in vivo* ESR spectroscopy technique has been developed to measure free radical reactions even in the whole animal non-invasively using nitroxide free radicals, which are sensitive to both redox state and ROS. Rates of penetration of nitroxide free radicals into the skin and their distribution in the skin have been measured by the ESR technique. Thus, the generation and distribution of radicals produced during normal metabolism or induced after irradiation of the skin by sunlight can be measured.

However, there are significant limitations to the use of ESR to detect radical intermediates in association with oxidative damage in cells and tissues. Some radicals have very short lifetimes under normal conditions. These very reactive radical species will be less likely to accumulate, because their measured steady state concentrations are dependent on the rates with which they react with surrounding molecules. Thus, more reactive radicals are less readily observed by standard ESR techniques. To measure concentrations of very reactive radicals, spin-trapping agents such as α-phenyl-N-tert-butylnitron (PBN) and 5,5-dimethyl-1-pyrroline-N-oxide (DMPO) are used *in vivo*. But interpretation of the data concerning concentrations of the trapped radicals *in vivo* is complicated due to unknown mechanisms of metabolism of the spin traps and their respective radical adducts. The degradation of radical adducts of DMPO in cells can be very rapid.

There are specific markers of the attack of $^{\bullet}OH$ radical (DNA adducts, aromatic probes, amino acid

hydroxylation, and salicylate hydroxylation products) that are used for measuring $^{\bullet}OH$ *in vivo*. Of these and other biomarkers that indicate the intensity of an oxidative stress (aging-associated or associated with exposure to radiation or to other stressful environmental facts), measurements of 8-oxoG (or 8-oxodG) have become increasingly popular. Until quite recently, however, there were problems with the measurement techniques. In particular, earlier studies of the levels of induction and repair of this type of DNA damage used DNA that was isolated using either phenol or other organic solvents, which resulted in a high background level of the damage, while the use of sodium iodide indicated at least a 10-fold lower background level of the damage. The immunohistochemical detection of 8-oxodG allows detection of this damage *in situ*, therefore avoiding DNA damage during the DNA isolation and preparation for analysis. It is worth noting, however, that the published data on 8-oxodG are in agreement with the major conclusions derived from earlier studies, i.e., there is accumulation of 8-oxodG in DNA of cells and tissues with chronological age.

One of the most important pathways of oxidation of proteins by the ROS is conversion of side chain amino groups to carbonyl derivatives called protein carbonyls. Measurements of the levels of protein carbonyls in human body fluids have been used to estimate the levels of oxidative stress *in vivo*. Various tests have been developed to measure lipid peroxidation in human tissues and body fluids. The older method of measurement, the thiobarbituric acid assay, can be improved upon by a more accurate and sensitive method, which is based on the non-enzymatic production of a group of prostaglandin-like compounds arising from ROS attack on phospholipids.

Molecular-Physiological and Pathological Responses of Mammalian Cells to Oxidative Damage

Regulatory Role of Reactive Oxidants and Antioxidants

Cellular Response to Oxidative Stress and Sensitivity of Transcription Factors to ROS That Determine the Response It is established that control of gene expression is required for proper response to stress and that transcription factors play a crucial role in regulating these processes. Modification of the redox state of certain transcription factors can contribute to or inhibit the formation of specific complexes between these factors and their cognate DNA elements in mammalian cells. This mechanism is similar to the mechanism of regulation of gene expression in response to oxidative stress in bacteria through a change in the DNA-binding specificity of the bacterial transcriptional regulatory protein, OxyR. For example, formation of a regulatory disulfide bond in OxyR transcription factor activates it *in vitro*, while studies of the *in vivo* oxidation of this protein indicate its oxidation within 30 seconds in response to hydrogen peroxide. The oxidation is transient and is associated with activation of transcription of OxyR-regulated genes. In mammalian cells, there are several pathways of regulation of transcription factors by ROS.

Role of the Nrf2-Keap 1 Complex of Proteins in the Induction of Genes Encoding Antioxidant Proteins in Response to an Oxidative Stress A molecular defense system provides cytoprotection against oxidative stress and against electrophiles by the expression of antioxidant proteins and phase 2 detoxifying enzymes, respectively. A key element of this system that regulates the resistance of cells to ROS or electrophiles is a cis-acting element called the antioxidant responsive element (ARE) or electrophile responsive element (EpRE), which is located within the regulatory region of a number genes that are induced upon exposure to low levels of ROS or electrophiles. During the past 10 years, it has become evident that among the ARE/EpRE binding transcription factors, Nrf2 plays a major role. This protein was first isolated by two independent groups of researchers in the mid-1990s as a protein closely related to p4 NF-E2. Therefore, its complete name is NF-E2-related factor 2.

Another important element in the response to oxidative stress or electrophiles is Keap1 (Kelch-like ECH associating protein 1). Keap 1 determines the intracellular localization of Nrf2 by binding and thus sequestering Nrf2 in the cytoplasm (recall that Nrf2 is a transcription factor that can function only upon reaching its cognate DNA sequences). However, ROS or electrophiles can induce the release of Nrf2 from its inhibiting 'partner' Keap 1 and allow Nrf2 to accumulate in the nucleus and then interact with the cognate DNA elements to enhance the expression of a number of cytoprotective genes, in which these elements are placed.

Cell Replication and Differentiation Oxidants can regulate cell replication in a dose-dependent manner. Usually, low levels of exogenous oxidants stimulate cell replication, whereas high levels of oxidants inhibit it. Endogenously generated ROS, such as superoxide radical and hydrogen peroxide, can act in various cells as signals augmenting the proliferative response. Transcription factors and/or kinases

involved in growth signal transduction pathways can mediate these effects through regulation of the expression of genes and the activity of proteins that control the cell cycle.

For example, in human hepatoma cells, ROS-induced proliferation correlated well with the extracellular signal-regulated kinase (but not JNK or p38) activity. Studies using mitogen-activated protein kinase (MAPK) inhibitors have shown that the MAPK signaling pathway can lead to activation of cell proliferation, which can be triggered by ROS.

Since Allen and Balin demonstrated that manganese superoxide dismutase (MnSOD) activity increased by as much as 46-fold during the differentiation of *Physarum polycephalum*, this enzyme has been found to be increased as differentiation proceeds in various other biological systems. Moreover, transfection of rodent cells with MnSOD promotes their differentiation. Liposomes containing SOD can induce differentiation in some tumor cells, such as Friend erythroleukemia cells. Thus, factors controlling redox state such as the levels of SOD can be involved in the mechanisms of differentiation.

Paradoxically, not only the antioxidant enzymes, but also the oxidant H_2O_2 can induce cell differentiation in some systems. This paradox can be partially resolved if one remembers that SOD is involved in the mechanisms of production of intracellular H_2O_2. On the other hand, oxidative stress induced by H_2O_2 can result in an adaptive response, resulting in an increased activity of SOD.

Pathophysiological and Gerontological Aspects

Primary Targets of Oxidative Injury, Physiological Aging, and Diseases Associated with Aging: Rationale for Prevention of These Disease by Optimal Use of Antioxidants

Oxidative Damage to Nuclear DNA and Replicative Cell Aging and Initiation of Carcinogenesis Even under normal conditions, the cell's DNA is bombarded by many ROS each minute. Most spontaneous oxidative DNA damage is removed by DNA repair systems. But, as shown in many radiobiological studies, these repair systems are not 100% effective. Thus, oxidative damage to DNA and, in particular, the difficult to repair complex DNA damage that can be produced by hydroxyl radicals might accumulate during aging.

After it was discovered in the mid-1980s that the major oxidative damage to DNA in cells exposed to ionizing radiation is 8-oxodG, a number of studies demonstrated that normal aging of human and rodent tissues is associated with an accumulation of this oxidative DNA damage product.

8-oxodG is a strong mutageneic and (pre)carcinogenic oxidative lesion, and DNA damage can be a major player in the mechanisms of the aging-associated carcinogenesis and pathogenesis of chronic diseases, including atherosclerosis and some neurodegenerative disorders. Studies in which DNA was isolated by a more gentle sodium iodide technique showed that there is a significant increase in the levels of 8-oxodG in DNA in tissues of mice and rats with age. For example, there was an 84% increase in 8-oxodG in nuclear DNA isolated from liver and a 37% increase in 8-oxodG in nuclear DNA from the hearts of male F-344 rats.

Oxidative Damage to Lipids, Proteins, and Lipoproteins and Promotion of Carcinogenesis and Degenerative Diseases The classical model of carcinogenesis has been operationally divided into initiation (mutation and formation of a transformed clone), promotion (expansion of the clone), and progression (malignant evolution of tumor cells toward increased malignancy). It is established that H_2O_2 and some organic peroxides stimulate the promotion of skin cells to develop into papillomas. These oxidants can also stimulate progression of papillomas into carcinomas. Agents that generate ROS are also tumor promoters and/or can mimic the biochemical action of tumor promoters in a variety of other cells and tissues besides the skin. On the other hand, various antioxidants inhibit tumor promotion.

Data obtained using biophysical, biochemical, and histochemical methods indicate that lipofuscin is a lipid-protein adduct complexed with metal ions, including copper and iron. These metals may be involved in the pathogenic mechanisms of age-dependent accumulation of lipofuscin by activation of lipid peroxidation. Direct or metal-catalyzed reactions of oxygen and unsaturated fatty acids also contribute to the age-related accumulation of lipofuscin. This accumulation may play a role in the functional decline of postmitotic cells.

One of the more serious end points of the activation of lipid peroxidation and the formation of oxidative damage to lipoproteins is the atherosclerotic lesions that develop in blood vessels. A significant decrease in the activity of antioxidant enzymes, in particular, superoxide dismutase and glutathione peroxidase, has been found in atherosclerotic tissue, while ROS can induce oxidative damage to both the lipid and protein components of low-density lipoprotein (LDL) and other lipoproteins.

Accordingly, oxidative modification changes the properties of LDLs and high-density lipoproteins in ways that are known to promote atherogenesis. Furthermore, lipoprotein particles with physicochemical properties similar to oxidized LDL have been found in human atherosclerotic lesions. Oxidized amino acids have been found in proteins isolated from atherosclerotic lesions. The pattern of these amino acids implicates reactive intermediates generated by myeloperoxidase, a major phagocyte enzyme. This suggests that myeloperoxidase promotes LDL oxidation *in vivo* and that this oxidation is involved in the formation of atherosclerotic lesions.

The atherogenic potential of LDLs is increased through the non-enzymatic binding of glucose to the protein component, that is, by glycation of the protein. The combined effect of oxidation and glycation, which is exaggerated in diabetic individuals, can foster the development of atherosclerosis.

However, studies of cohorts of humans with a high risk of atherosclerosis have not shown significant benefit from vitamin E or other antioxidants. At the moment, there is no clinical evidence demonstrating that antioxidant supplements are of value in the prevention of cardiovascular diseases in subjects at high risk, as was thought previously. However, the picture is complicated by the observation that even the most popular antioxidants may, under certain conditions, become pro-oxidants. This may be why the use of beta carotene for the prevention of cancer in smokers led to an increase in cancer in the subjects studied.

There is some evidence, obtained on preclinical models of Alzheimer's disease (AD), Parkinson's disease, and Huntington's disease, for the primary role of protein oxidation in the initial steps of these neurodegenerative diseases. Aging is a risk factor in the development of these diseases. The increase in oxidized proteins isolated from the brains of humans suffering from these diseases can reflect a mechanism of initiation of a cascade of biochemical events that results in the neurodegeneration.

Indeed, almost all amino acids in proteins are potential targets for oxidation by ROS. Methionine and cysteine residues are particularly sensitive to oxidative damage, while the formations of carbonyl derivatives of cysteine as well as lysine, arginine, proline, histidine, and threonine residues comprise the most widely studied oxidative modifications of proteins. Multiple studies have confirmed the initial observation by E. R. Stadtman of the aging-related increase of protein carbonyls in human cells and tissues. Furthermore, elevated levels of carbonyl proteins have been observed in the two major human progeroid syndromes and in some of the aging-related common diseases, including Alzheimer's disease.

Thus, oxidatively damaged DNA, lipids, and proteins accumulate in human and animal tissues with chronological age. In addition to the age-related increase in the level of protein carbonyl content, there is also an increase in the amount of oxidized methionine and cross-linked and glycated proteins. These observations help explain the earlier discovery of David Gershon of the aging-related accumulation in mammalian tissues of a fraction of less active or inactive enzymes, which have increased susceptibility to heat inactivation.

However, the mechanisms leading to the aging-related increase in the levels of oxidatively damaged proteins remain obscure. It is hypothesized that one such mechanism is increased ROS production associated with reduced functioning of proteasome-based mechanisms of degradation of oxidized proteins. It is still not known whether ubiquitylation is necessary for the degradation of such 'aged' *in vivo* proteins.

Oxidative Injury-Dependent Pathway of the Apoptotic/Programmed Cell Death Mechanisms Programmed cell death plays an important role during aging of various tissues and cells *in vivo*. For example, age-dependent apoptotic cell death has been documented in the aged brain. However, human fibroblasts aged *in vitro* are resistant to apoptosis. But unlike aged fibroblasts, human endothelial cells undergo age-associated cell death during *in vitro* senescence, which is also associated with a significant increase in the intracellular concentration of ROS. Thus, a link between aging-related ROS production (and therefore oxidative damage to biomolecules) and aging-associated apoptotic cell death exists, although this link seems to be a cell type-specific phenomenon.

Oxidative Damage to Intracellular Components of Connective Tissue and Skin Aging ROS such as hydrogen peroxide modulate the activity of signaling molecules that induce expression of extracellular matrix-degrading metalloproteinases (MMPs). This signaling in human skin can be blocked by antioxidants, confirming suggestions that redox reactions are involved in the regulation of MMP expression. On the other hand, UV light, which is responsible for human skin photo-aging, increases the activity of MMPs, in particular, MMP-1. Thus, systemic degradation of collagen by MMPs has been implicated in premature skin aging and a number of other disorders associated with accelerated aging.

Oxidative Damage to Mitochondrial DNA and Limit of Life Span of Animals and Humans Only mitochondrial DNA (mtDNA) is vulnerable to a direct attack of hydroxyl radical produced in the mitochondria, because hydroxyl radical has a very short half-life (0.3 ns) and diffuses less than 10 molecular diameters before it reacts. Therefore, this radical causes DNA lesions near its origin.

Superoxide radical or H_2O_2 can react with unsaturated lipids, which are enriched in the inner mitochondrial membranes. It has been shown that lipid peroxidation of these membranes is associated with damage of mtDNA. The vulnerability of mtDNA to oxidative damage is amplified by a lack of histones, which can partially protect nuclear DNA in chromatin. The nucleotide excision DNA repair pathway, which could contribute to repair of oxidative damage, is absent in mitochondria.

The content of 8-oxodG measured in mtDNA isolated from autopsied myocardium of Japanese patients increases exponentially with age and in parallel with the accumulation of mtDNA that contains a 7.4 kbp deletion. The age-dependent increase in both these mtDNA alterations is correlated with an age-dependent increase in the death rate in Japan.

An age-dependent increase in the proportion of mtDNA with a common 5-kb deletion compared to normal mtDNA has been found to occur in the skeletal muscles of American patients. This mtDNA deletion increases exponentially and in parallel with the age-dependent increase in the human death rate in the United States. In all cases, the ratio of altered mtDNA to normal mtDNA and the death rate in both countries double each 7–8.8 years after age 30–40.

It is generally believed that the major mechanisms limiting the proliferative life span of replicative cells aged *in vitro* involve telomere shortening. It is interesting that telomeric DNA (tDNA) is particularly vulnerable to various sources of oxidative damage. The special features of instability and repair of mtDNA and tDNA suggest the possibility that together they might play a role in limiting the life span of human postmitotic and replicative cells, respectively.

Oxidative Stress and Premature or Accelerated Aging

The Late Biological Effects of Ionizing Radiation Exposure to ionizing radiation results in an increase in oxidative damage to DNA, protein, and lipids in a dose-dependent manner. This increase is mainly the result of the increased rate of production of ROS and their direct attack on biomolecules.

Late biological effects of ionizing radiation include accelerated aging on different levels. For example, an increase in the rate of the age-dependent accumulation of DNA damage in brain cells and of cross-links in collagen molecules has been observed in rodent tissues many months after they were exposed to ionizing radiation.

Photo-aging of the Skin and Accelerated Aging of Collagen Connected with Diabetes The rate of aging of human skin is related to the combined effects of chronologic aging and actinic damage, referred to as photo-aging. The destruction of several antioxidant enzymes, including SOD and catalase, occurs in UV-irradiated keratinocytes *in vitro* and in the epidermis and dermis of skin exposed to UV light *in vivo*. Thus, skin proteins are vulnerable to UV light, and this vulnerability is amplified by the decline in enzymatic antioxidant defenses.

Exposure of skin to UV light results in lipid peroxidation and is associated with the production of singlet oxygen. In addition, UV-induced oxidative damage in human skin can be mediated by sensitized molecules, including tryptophan, riboflavin, and pyridoxine. There is direct evidence, obtained by measurement of free radical signal intensity using ESR techniques, that UV radiation produces ROS and carbon-centered radicals in human skin. Photochemically generated ROS induce various alterations, including cross-links in collagen that contribute to the molecular mechanisms of photo-aging of mammalian skin.

In addition, there is evidence that certain skin metalloproteinases are involved in photo-aging and are induced by ROS leading to the degradation of collagen types I, II, and III. For example, induction of a major enzyme (MMP-1) in human skin by UV light requires production of hydrogen peroxide. Therefore, ROS could contribute to the reduction of collagen content in human skin with chronological age and/or photo-aging, indirectly through the induction of MMPs in the skin, specifically MMP-1.

The content of lipid peroxidation products is increased in the aged epidermis of animals and humans. Accordingly, in the senescence-accelerated mouse model, an increase in lipid peroxide levels in the skin precedes the accelerated senescent clinical signs of mutant mouse skin.

Skin senescence and aging-related skin diseases may be associated with a combination of oxidative modifications in addition to the non-enzymatic glycation of skin proteins. Glycation of collagen is substantially elevated in diabetic patients as compared with age-matched controls. This phenomenon can be referred to as accelerated aging of collagen, because collagen glycation increases almost linearly with normal aging. Collagen isolated from tissues of

long-term diabetics is more stable in comparison with age-matched controls. Mechanisms of the stabilization of collagen molecules during normal and diabetes-accelerated aging include cross-linking of the molecules via glucose.

Summary

Of the numerous modifications of various biomolecules induced by ROS, a few can be identified as oxidative damage associated with the process of aging. One of these oxidative damage products is 8-oxoguanine. Its steady accumulation with age in mitochondrial DNA of hearts and brains, and in nuclear DNA of replicative cells, can be correlated with the age-dependent increase in the risk of chronic heart and brain disease and cancer, respectively. These observations lend a strong credence to Harman's free radical theory of aging. But the picture that emerges is more complex than one simply due to damaged products.

First, different ROS play a specific role in many processes, including intracellular signal transduction, cell proliferation, differentiation, and apoptotic cell death mechanisms, which are required for both normal development and maintenance of adult health. Different ROS are endowed with different biophysical and biochemical characteristics, such as half-life, affinity to certain receptors, and chemical reactivity with certain groups in macromolecules including bases in DNA. These characteristics influence the physiological role of the different ROS.

Second, the physiological role of at least some of the ROS can be mediated by transcription factors, which are both sensors of the levels of ROS and/or of redox state and regulators of genes that determine cellular response to oxidative stress. These genes are among those that modulate cell replication and differentiation. This provides a mechanism in which ROS are involved in both the regulation of cell replication and differentiation and in the pathogenesis of diseases connected with deregulation of these processes.

See also: Cellular Aging: Growth Factors and Cellular Senescence; DNA and Gene Expression.

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Pain and Presbyalgos

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Glossary

Nociception – Sensory properties of pain and pain perceptions. Determined, in part, by type, intensity, location, duration of the stimulus and resulting activity in nociceptive pathways in most cases. Central pain and other conditions involving referred pain, reflex sympathetic dystrophy, or causalgia are accepted as involving activity in nociceptive pathways. Sensory qualities of different nociceptive events may differ.

Nociceptor – A receptor preferentially sensitive to a noxious stimulus or to a stimulus that would become noxious if prolonged or sufficiently intense.

Pain – An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. Pain is always subjective. Activity induced in the nociceptor or nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state.

Pain Affect – Pain can elicit two distinct emotional components. One, the primary affective component, is associated with the immediate sensory/perceptual experience and is strongly related to cotemporal sensory pain experience (nociception). Another, the secondary affective component of pain, is determined more by past history of the painful experience, personality, cognitive appraisals, and meaning of the pain to the individual. This dimension of pain can be equated with suffering (see **Table 1**).

Presbyalgos – (*presby*, old; *algos*, pain) A general term used to describe age changes in pain sensitivity, perception, affect, and behavior. It differs from the terms employed to describe age changes in vision (presbyopia: *opia*, vision) or audition (presbycusis, *cusis* or *acusis*, hearing), which are restricted to losses in sensory acuity. Presbyalgos includes sensory, cognitive, affective, and behavioral components and is not a generalized decrease in sensitivity to pain in old age, a phenomenon that likely does not exist. Social cohort influences on meaning of pain to the individual, individual differences in definition of pain and its properties, as well as individual differences in definition of acceptable pain behaviors must not be interpreted as age differences in nociception.

Introduction

The topic of geriatric **pain** has not received attention in the field of gerontology until recently. This article reviews what is currently known about pain in relation to age in the later years of life. Pain is defined and a preliminary definition of **presbyalgos** is presented. The relations between old age and different types of the human experiences of pain are reviewed. These include experimental pain, acute procedural and clinical pain, postsurgical pain, atypical pain, and chronic pain. Considerations for pain assessment in the geriatric population are discussed, and needs for future research to improve pain assessment in specific populations of elderly pain patients are suggested.

There are at least four factors that might influence pain perception in the later years of life. These include loss of receptors for pain (nociceptors), changes in conduction properties of primary nociceptive (pain) afferents, changes in central mechanisms subserving the coding and sensation of pain, and psychosocial influences affecting the meaning of pain to the individual. The psychosocial influences that may differ between younger and older adults include those due to experiences with pain over the lifetime (developmental effects) and those due to social history or secular change (birth cohort effects) (*see* Touch and Proprioception).

Currently, it is unclear whether pain perception is influenced by age in the later years of life. This is due

in large part to confusions concerning not only the definition of what pain is, but also questions by some as to whether pain can be measured. As for pain, no discrete physiological markers exist for old age. Yet, this difficulty in definition and measurement of age has not deterred research related to the phenomena of biological, psychological, and sociological aging. Therefore, other reasons must account for the limited understanding of the effects of age on pain.

The field of pain research has expanded enormously in the past decade. This is in part due to (1) successful efforts to define the phenomenon of pain; (2) recognition that different types of pain exist (pain is not a unitary phenomenon); (3) a better understanding of some of the neural mechanisms of specific pain-related phenomenon; and (4) insights into both the impact of pain on the individual as well as the impact of individual differences (i.e., personality) on expression of pain symptoms and behaviors. Nevertheless, the psychophysical evaluation of the effect of age on pain has a history differing considerably from that of almost all other sensory modalities.

Although the physical, physiological, and psychological attributes of most sensory modalities have been carefully characterized, those defining pain are far less well documented. There are at least four reasons for the comparative lag in the understanding of the effects of old age on pain. The *first* reason relates to the precision to which stimuli that activate the various sensory modalities can be controlled and quantified. For example, in auditory or visual psychophysics, the ease of quantification and control of stimuli has facilitated precise definition of the effects of aging on hearing and vision. In contrast, quantification and control of stimuli that produce pain are far less precise. This is due, in large part, to the fact that these stimuli are potentially damaging and difficult to present repeatedly with the same effect, and many lack a natural physical counterpart (i.e., electrical shock).

The *second* reason relates to attitudes about pain. The human experience of pain has sensory-discriminative, motivational-emotional, and cognitive-evaluative dimensions. The operational definitions for measurement of these dimensions, however, remain a topic of considerable debate. Some, wrongly, even consider that pain is a private experience that is not measurable.

A *third* reason is the magnitude of the effort that has been directed toward the study of the other sensory modalities versus the study of pain in relation to age. The number of researchers exploring the effects of age on the psychophysics of other sensory modalities has been far greater than that devoted to the study of adult age differences in pain.

A *final* reason is that it is often simply assumed that age results in a loss of pain perception. In the clinical setting, particularly multidisciplinary pain clinics, it has also been assumed that the older adult with a chronic pain complaint is not a good candidate for treatment. Such ageist attitudes, combined with the view that pain is not measurable and the perceived difficulty in stimulus presentation and control, have limited advances in our understanding of adult developmental factors that may influence pain perception.

Definition of Pain

Pain is defined according to Mersky and by the International Association for the Study of Pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (Mersky, 1986: S217). It must be explicitly recognized that pain is an experience, not simply a response to a stimulus. Thus, "activity induced in the nociceptor and nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state, even though we may well appreciate that pain most often has a proximate physical cause" (Mersky, 1986: S217). Two situations in which the proximate physical causes of pain are more clearly and quantifiably specified are in acute, procedural pain (e.g., injection, third molar extraction) and in experimental studies of pain in the laboratory. To our knowledge there are no systematic studies of age differences in procedural pain. A number of laboratory studies of the effects of age on pain sensation have been published, and these are reviewed below.

Dimensions of Pain

Human pain has been described as having sensory, emotional, and cognitive dimensions. The sensory components of pain are described in terms of location, temporal properties, quality, and quantity. Quantity in terms of pain intensity is the property most frequently studied, usually by verbal descriptor scales such as the widely used McGill Pain Questionnaire or by visual analog scales (VAs).

Effects of aging on the motivational-emotional dimension of pain has received less attention than the sensory-discriminative dimension. Recently it has been shown that two quite different emotional components of pain exist. One is associated with the immediate unpleasantness of pain. This emotional component (stage 1 pain affect) usually does not exist in the absence of the sensory qualities of a painful event and is primarily, but not uniquely, determined

by pain intensity. The second emotional component of pain (stage 2 pain affect) is associated with broader feelings or moods that are in large part determined by interactions of the history of pain with cognitive-evaluative processes (meanings, expectancies, memories, social context, and pain-related limitations in activities of daily living [PRL-ADLs]). Stage 2 pain affect represents suffering that often occurs in the absence of the nociceptive event or that occurs for any threat to personal integrity. The effect of age on stage 2 pain affect has not been systematically studied.

The cognitive-evaluative dimension of pain has received even less attention in relation to aging. The cognitive aspects of pain involve the meaning of the pain to the individual and expectancies concerning the pain, as well as the contexts in which it occurs, its impact on voluntary or obligatory ADLs (PRL-ADLs) and its effects on social, family, and occupational activities. The cognitive dimension of pain is now recognized to have a greater impact on the two emotional components than on the sensory dimension of pain, with a larger effect on stage 2 than stage 1 pain affect.

Figure 1 serves as a model to review the known effects of age on pain. The different dimensions of pain are illustrated in this figure. In this figure, a nociceptive event results in specific sensations that can be appreciated in terms of intensity, location, temporal quality, as well as other qualities. Cognitive appraisals, combined with the sensory quality of the nociceptive sensation(s) and autonomic arousal, condition the immediate unpleasantness of the painful event (stage 1 affect). The second type of emotional response to pain (stage 2 affect in **Figure 1**), however, is mediated by more complex cognitive events that are influenced not only by the sensory quality and primary affective response but also by the current context and past history with the same or similar pains.

Presbyalgos

Table 1 summarizes possible age effects on the different dimensions of the human pain experience as shown in **Figure 1**. A common view is that the elderly have reduced sensitivity to pain that parallels the well-documented changes that occur in the major senses. Presbyopia (*opia*, vision) is the most common physiological marker for onset of old age for the eye. Presbyopia begins in the later fourth and early fifth decade of life and results in decreased ability to focus on near objects. It is due to loss of flexibility and accommodation ability of the lens. Presbycusis (*cusis*, hearing) is a decrease in hearing that is characterized psycho-physically in terms of increased thresholds for pure tones. It is bilaterally symmetrical, progressive, and irreversible and affects higher before lower frequencies. Although presbycusis is, as presbyopia, almost universal, it affects men to a greater degree than women. Its onset, which is often

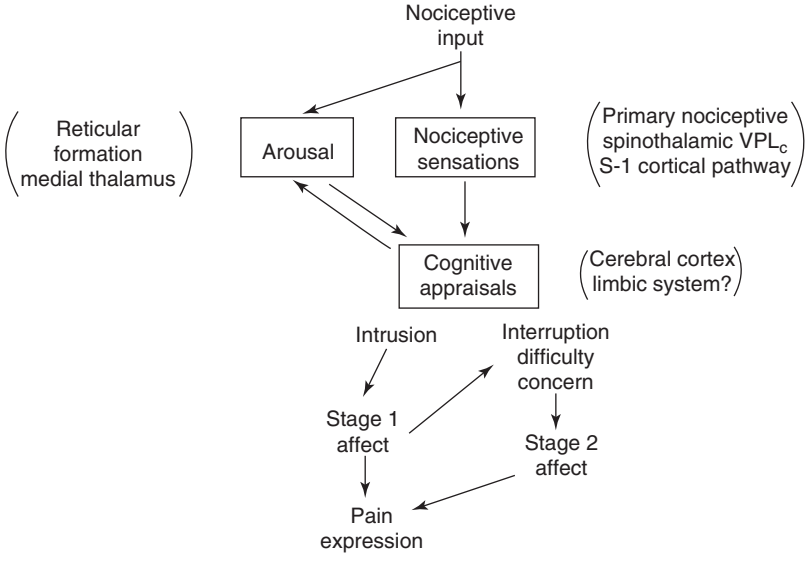

Figure 1 A schematic illustrating the interactions among the various dimensions of pain. Nociceptive input (a painful event) has specific sensory properties that are dependent on the type of pain. The perceived qualities of pain interact with cognitive evaluative processes influencing, to differing degrees stage 1 (immediate unpleasantness of pain) and stage 2 (pain-related suffering) pain affect. Adapted from Price DD and Harkins SW (1992) The affective-motivational dimension of pain: A two-stage model. *American Pain Society Journal* 1: 229–239.

Table 1 Characteristics of presbyalgos

I. Sensory components: Nociception
  A. Characteristics
    1. Determined by stimulus intensity, location, duration, type
    2. Sensory qualities differ for types of pain (e.g., superficial versus deep pain)
  B. Possible age effects
    1. Increased pain thresholds (Not likely)
    2. Increased pain tolerance (Not likely)
    3. Reduced ability to discriminate between pain of various intensities (Not likely)
    4. Reduced ability to discriminate among different pains (Difficult to assess)
    5. Increased frequency of atypical pain as a symptom of disease processes (Definitely)
    6. Increased frequency of chronic pain (Definitely)
II. Primary affective components: Stage 1 pain affect
  A. Characteristics
    1. Strongly related to pain intensity and autonomic nervous system
    2. Related to appraisal of the present and short-term future
    3. Mediated by meaning and cognitive appraisal
  B. Possible age effects
    1. Reduced unpleasantness of pain, due to reduced sensory intensity of pain in general (Not likely)
    2. Reduced unpleasantness of pain due to decreased arousal, exteroceptive (sight, sound), and interoceptive (startle, autonomic) responses resulting in reduced segmental responses to painful injury (No evidence exists for acute pain, may be true of chronic pain)
    3. Reduced general aversiveness of nociceptive stimuli (Unlikely)
    4. Decreased perception of threat, distress, annoyance associated with the intensity of the painful sensation and its accompanying arousal (Unlikely for acute pain)
    5. Differences or changes in cognitive appraisal (Likely)
III. Secondary affective components of pain: Stage 2 pain affect
  A. Characteristics
    1. Related to past and long-term future
    2. Cognitive appraisal
    3. Related to or representative of suffering
    4. Not measurable in experimental studies of pain
    5. Stage 2 pain affect shares many properties of emotional suffering. Suffering is defined here as the state of severe distress associated with events that threaten the intactness of the person. There is confusion between chronic pain and suffering because disease models dominate thinking concerning pain
    6. Unameliorated pain-related suffering (stage 2 affect) requires different interventions than those traditionally used for control of the sensory intensity or the primary affective components of pain
  B. Possible age effects
    1. No systematic studies exist concerning effects of age on the secondary affective component of human pain, but the results shown in **Figure 5** suggest a reduction in stage 2 pain affect with age

a little later than that of presbyopia, indicates the beginnings of old age for the ear. It is due to damage to the hair cells (cilia) of the cochlea and, likely secondarily, to loss of first-order neurons in the acoustic portion of the eighth cranial nerve (sensorineural hearing loss) (*see* Hearing, Vision).

Types of Pain

A phenomenon parallel to presbyopia and presbycusis that would adversely influence ability to perceived painful stimuli could be termed presbyalgos (*algos*, pain). However, a decrease in pain sensitivity with age and associated reduction in either nociceptors or in conduction properties of nociceptive afferents has not been consistently demonstrated in experimental studies of pain.

Experimental Pain

The question of whether age influences the way in which pain is perceived can be assessed in the laboratory. A number of studies have evaluated the effects of aging on experimental pain, employing the psycho-physical end points of threshold, reaction, tolerance, and discriminability. These studies are untidy. Some indicate that there is a loss of pain sensitivity with age, whereas others indicate that the elderly are more pain sensitive compared to younger adults. A third grouping of these studies indicates

that age has no effect on pain sensitivity. These studies are summarized in **Table 2**.

The various outcomes in experimental studies of pain (**Table 2**) reflect number of substantive differences between the studies. These studies vary in stimuli employed, psychophysical end point and method, the age and gender of subjects, as well as subject selection and screening criteria. The instructions and degree of practice on the psychophysical task also likely influence variability among these experimental studies.

It is likely that aging per se has minimal effect on sensitivity to superficial, acute pain. This conclusion is based largely upon recent studies employing contact thermal stimulation. This method of study of cutaneous pain in the laboratory has been demonstrated to be particularly powerful for assessing individual differences in acute pain sensitivity. **Figure 2** presents results from one of these studies. The results of this study indicated a significant, but trival, difference in pain ratings between younger, middle-aged, and older volunteer subjects.

Some earlier studies do indicate increased thresholds for radiant heat-induced thermal pain, whereas others indicated no effects of age (see **Table 2**). We agree with those researchers who have found that pain intensity ratings are similar in older and younger adults if care is taken in subject selection, instructions, and practice. Instructions are critical. When they have clearly indicated that responses are to be made to the pricking or first pain sensation in studies employing thermal stimuli, no age effects have been found.

Acute Procedural Pain

As mentioned earlier, there are, to our knowledge, no systematic studies of age differences in procedural pain in older adults. Procedural pain is defined here as pain resulting from a specific, limited, invasive procedure. Procedural pain has been systematically studied in evaluation of neonatal and pediatric pain (e.g., studies of reaction to heel prick in neonates or to allergy injections in young children). It is surprising that so little research has focused on this area in geriatric patients. There may well be significant hyperalgesia and allodynia in the frail elderly that would be demonstrable by carefully conceived and excuted studies of pain in the old-old and oldest-old.

Postsurgical Pain

Currently available information indicates that the intensity of postsurgical pain in different age groups is similar in quantity and quality. Some researchers, however, found that older adults received less analgesia than younger adults and that this may contribute to a longer hospital stay during post surgery recovery in geriatric patients. Further research is sorely needed in this area and should focus on quality and quantity of procedural and postsurgical pain in relation to age in the later years of life. Long-term follow-up would indicate whether the elderly are differentially at risk for postsurgical causalgia.

Cancer Pain

Cancer pain is a form of acute pain that is related to the type and status of the cancer. Pain in cancer patients occurs frequently. In the elderly cancer patient, any apparent decrease in sensitivity to pain is likely due to less effective report of pain than to actual losses of sensorineural processes subserving pain sensibilities. This impact of cultural inhibition on complaining of pain, and less effective reporting of pain in the old has not been systematically evaluated. Nevertheless, pain in the elderly is more likely to produce significant impairment of psychological, social, and physical function than in younger individuals (*see* Cancer and Age).

Management of cancer pain begins with efforts to control the underlying disease with standard modalities. An important principle of pharmacotherapy is to suppress the pain before it becomes severe, and to give continuous effective doses rather than to attempt to treat episodically. Elderly patients are more responsive to smaller doses than younger persons because of a somewhat diminished metabolism of the drugs (pharmacokinetic effects) and an enhanced effect at the cellular level in the central nervous system (pharmacodynamic effects) (*see* Pharmacology).

In the elderly it is best to use drugs with a short half-life, prescribe one drug at a time, begin with low doses, and continue trial for an adequate period. In addition to the usual analgesics, other non-pharmacological measures frequently used to aid pain control in younger cancer patients may be helpful. These include various forms of nerve stimulation, physical and occupational therapy, sectioning of nerves surgically, or psychotherapy.

Atypical Pain Presentation

Although the evidence is untidy concerning experimental pain sensitivity in old age, there is no question that important age differences exist with regard to acute pain as a symptom in the older patient. Silent or painless acute myocardial infarction (MI) occurs more frequently in the elderly (up to 30%) than in younger patients (23%). Pain consequent to MI develops when sufficient levels of afferent impulses are reached and when an appropriate

Table 2 Laboratory studies of the effect of age on psychophysical indices of pain sensitivity[a]

Stimulus	*Source (Reference)*	*Psychophysical end points and findings*
1. Thermal		
A. Radiant heat	Schumacher et al., 1940	Sensory thresholds No age effects
	Hardy et al., 1943	Sensory thresholds No age effects
	Chapman, 1944	Sensory thresholds Higher in elderly Reaction thresholds Higher in elderly
	Chapman and Jones, 1944	Sensory thresholds Higher in elderly Reaction thresholds Higher in elderly
	Birren et al., 1950	Pain sensory thresholds No age effects Pain reaction thresholds No age effects
	Sherman and Robillard, 1964a, 1964b	Sensory thresholds Higher in elderly Reaction thresholds Higher in elderly
	Procacci et al., 1970	Sensory thresholds Higher in elderly
	Clark and Mehl, 1971	Sensory thresholds Higher in 55-year-olds compared to younger adults
B. Contact heat	Kenshalo, 1986	Sensory thresholds No age effects
	Harkins et al., 1986	Magnitude matching Slight age effects (see text and **Figure 2**)
C. Cold pressor	Walsh et al., 1989	Tolerance (time) Males: Lower with increasing age Females: Minimal increase with increasing age
2. Electrical shock		
A. Cutaneous	Collins and Stone, 1966	Sensory threshold Lower in elderly Tolerance Lower in elderly
	Tucker et al., 1989	Sensory threshold Higher in elderly
	Evans et al., 1992	Sensory thresholds No age effect in non-diabetics. Old diabetics higher thresholds than younger diabetics
B. Tooth	Mumford, 1965	Sensory threshold No age effects
	Mumford, 1968	Sensory threshold No age effects
	Harkins and Chapman, 1976	Sensory threshold No age effects Discrimination accuracy Lower in elderly Response bias Age effects: variable
	Harkins and Chapman, 1976	Sensory threshold No age effects Discrimination accuracy Lower in elderly
3. Pressure		
A. Achilles tendon	Woodrow et al., 1972	Tolerance Lower in elderly
	Jensen et al., 1992	Muscle tenderness and pressure pain to age 65 Sensory thresholds Higher in older

[a] From Harkins et al., 1992, as modified from Harkins SW and Warner MH (1980) Age and pain. In: Eisdorfer C (ed.) *Annual Review of Gerontology and Geriatrics*, Vol. 1, pp. 121–131. New York: Springer Publishing Company.

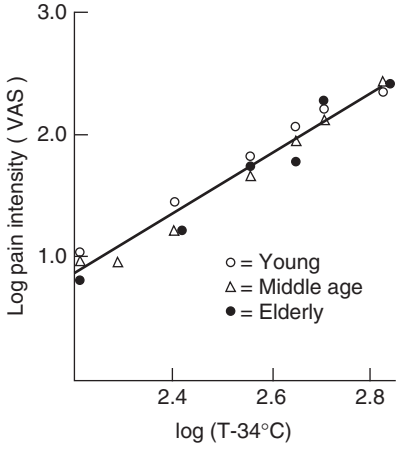

Figure 2 Psychophysical representation of reported pain intensity to brief heat pulses (43°C to 51°C; from an adapting temperature of 34°C) in young ($M = 25$ years), middle age ($M = 53$ years), and older ($M = 73$ years) community-dwelling, healthy individuals. Stimuli were delivered to the inner surface of the forearm. Stimulus intensity in natural log units on the ordinate and pain intensity (by visual analog scales; VAS) on the abscissa. Statistical results indicated a significant groups effect, with older individuals rating the intensity of the lower level stimuli as less intense compared to older subjects. At higher levels of stimulation, age groups were not different in their pain ratings. The significant age effect at lower intensities accounted for less than 1% of the variance in VAS pain ratings. Redrawn from Harkins SW, Price DD, and Martelli M (1986) Effects of age on pain perception: Thermonociception. *Journal of Gerontology* 41: 58–63.

activation of central ascending pathways has been established. In patients with a silent MI, such levels are apparently not reached, perhaps because of insufficient stimulation of the myocardium, decreased capacity for cephalad transmission, or for other unknown pathophysiological reasons affecting peripheral transmission.

Such age differences in presentation of pain as a symptom have been cited as evidence for a general decline with aging in pain sensitivity. This is inappropriate. First, pain does occur with acute MI in the majority of older heart attack patients. Stress testing suggests that depression of the S-T segment, without pain, occurs relatively frequently in both young and elderly adults. Thus, silent MIs may well reflect individual differences or pathophysiological changes in processes subserving referred pain and not generalized age changes in mechanisms subserving pain. Pain from deep structures and superficial pain represent quite different phenomena. Age differences in the one should not be generalized to the other without supporting empirical evidence.

Nonetheless, it is important clinically to recognize the increased prevalence of atypical presentation of pain as a symptom in the elderly. The direction of this is toward reduced not augmented pain. This reduction in incidence of acute pain, associated with certain conditions (e.g., myocardial ischemia) in the elderly, does not appear to hold true for recurrent or chronic pain.

Recurrent and Chronic Pain

Chronic pain has been defined as a pain that has not responded to treatment and that, according to different authorities, has lasted at least 1, 3, or 6 months. Chronic pain can be defined as pain that outlasts the normal healing period following tissue damage by 1 month. A time of approximately 1 month is preferred because failure to intervene will, in some cases, result in irreversible changes, increasing the likelihood that the pain will not be successfully treated.

There are many conditions causing pain that are treatable only to a certain point. It has been suggested that any pain that recurs with some regularity (whether there is or is not evidence of associated pathophysiological process that may give rise to pain), that can be expected to recur, that responds only to a degree to currently available interventions, and that negatively impacts on the quality of life of the individual in pain should be considered chronic and appropriate for referral to a multidisciplinary chronic pain diagnostic and treatment center.

The pattern of painful conditions in relation to old age with population-based survey studies indicating that aging is associated with an increase in musculoskeletal-related pains and a decrease in headaches and back pain typically seen in multidisciplinary pain clinical settings.

Figure 3 shows frequency of several chronic pains and **Figure 4** the intensity of these pains in younger and older community-dwelling individuals. Although the elderly may underutilize the multidisciplinary pain clinic, the population-based findings, shown in **Figures 3** and **4**, indicate that older adults are at increased risk for chronic pain compared to younger individuals (**Figure 3**).

Herpes zoster and the associated risk for postherpetic neuralgia increase with age and represent a major source of suffering in the elderly. The pain associated with postherpetic neuralgia is thought to arise from peripheral neurons that were damaged during the herpes zoster eruption. Another source of pain of unknown etiology is associated with parkinsonianism, a condition that increases with age in the later years of life. Approximately 50% of patients with parkinsonian's type movement disorders have significant pain, particularly in the lower limbs. Current thinking is that this pain is central in origin, but mechanisms and best modes of treatment are unclear.

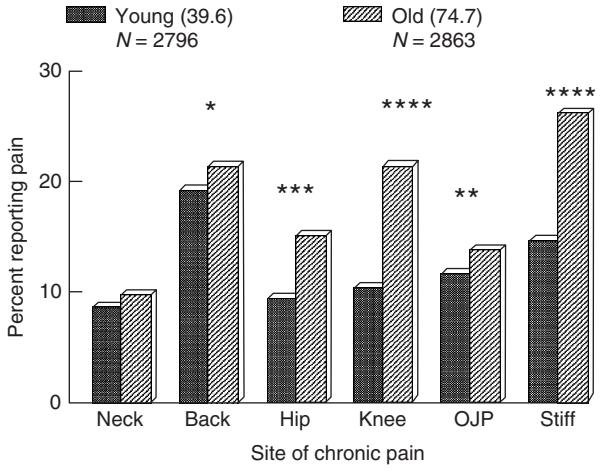

Figure 3 Chronic pain frequency in the general population in relation to age. Note that older individuals are at greater risk of pain from the back, hip, and knee compared to younger individuals. The older respondents also reported other joint pain (OJP) and stiff joints upon awakening compared to younger individuals. Chronic pain was defined here as a pain in the specified location lasting at least 1 month, which was present in the past week. From Harkins SW, Price DD, Bush FM, and Small R (1994) Geriatric pain. In: Wall PD and Melzack R (Eds.) *Textbook of Pain*. Edinburgh: Churchill Livingstone. (*$P<0.05$; **$P<0.01$; ***$P<0.001$; ****$P<0.0001$.)

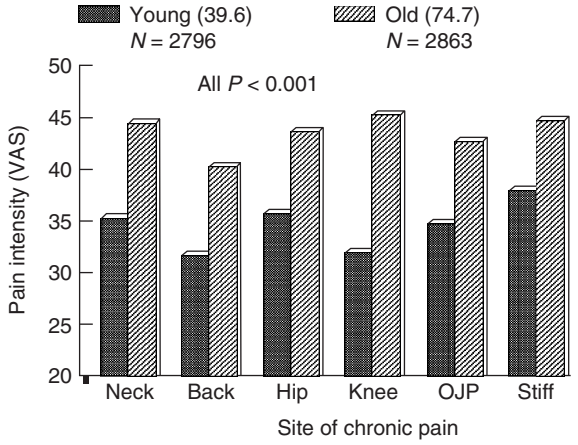

Figure 4 Chronic pain intensity in the general population in relation to age. Intensity ratings are for pains lasting at least 1 month that were present during the past week as in **Figure 3**. Fain intensity was greater in older compared to younger individuals (all $P<0.001$). Pain intensity based on visual analog scale (VAS) labeled 'no pain' at one extreme and 'very severe pain' at the other. Pain severity ratings range from 0 to 60 and were recorded in this figure as percent (i.e., 0 to 100%) of the original scale. Individuals reporting 0 pain over the past week were eliminated from this analysis. OJP, other joint pain; Stiff, stiff or swollen painful joints. Data from subjects as in **Figure 3**.

There is no convincing evidence that pain systems are influenced by the major cause of dementia in later life, dementia of the Alzheimer's type (DAT). Given the widespread effects of this central degenerative disease and its impact on attention, memory, and semantic abilities, it would not be surprising to find that perceptual aspects of pain were influenced by such disorders. More critical is the fact that ability to communicate is restricted in patients with DATs, and this will influence ability to communicate critical information concerning pain in these patients (*see* Dementia).

The epidemiology of pain in patients with age-related neurological degenerative disorders or in older individuals in long-term care settings, particularly the frail elderly, has not been the subject of focused study and merits attention. Considerable unnecessary suffering likely exists in these individuals.

The characteristics of presbyalgos (shown in **Table 1**) can be summarized in terms of the sensory, affective, and cognitive dimensions of pain as follows:

1. *Sensory dimension of pain*: As indicated in **Table 2** (see **Figure 1**), it is not likely that the elderly have increased thresholds, tolerance, and reactions, or decreased discriminability of pain intensity as determined in the laboratory. The elderly are at risk for atypical presentation of pain as a symptom and are more likely to suffer from chronic pain compared to younger individuals.

2. *Primary affective component of pain – Stage 1 pain affect*: Stage 1 pain affect in the model shown in **Figure 1** and **Table 1** is strongly influenced by the concurrent intensity of the noxious event, accompanying autonomic nervous system (ANS) activation (arousal), as well as a combination of situational and predispositional factors. It is unlikely that the primary affective component of pain is reduced with normal aging. There have been no studies of age differences in ANS arousal to acute pain. Empirical demonstration of such age differences, however, would not be strong evidence for age differences in pain perception because both sympathetic and parasympathetic control of end organs differ with age. Demonstration of age differences in ANS response to nociceptive stressors and no such differences for nonpainful stressors, or vice versa, could lead to informative research in this regard.

Similarly, as indicated in **Table 2**, it is unlikely that the elderly have a generalized reduction in the immediate unpleasantness (stage 1 pain affect) of a painful stimulus. That is, there is no substantive evidence that the elderly can be characterized as anhedonic for pain.

It is more likely that there are age differences in perception of threat, resulting distress, and accompanying general arousal and anxiety for previously experienced pain that is mediated by age-related

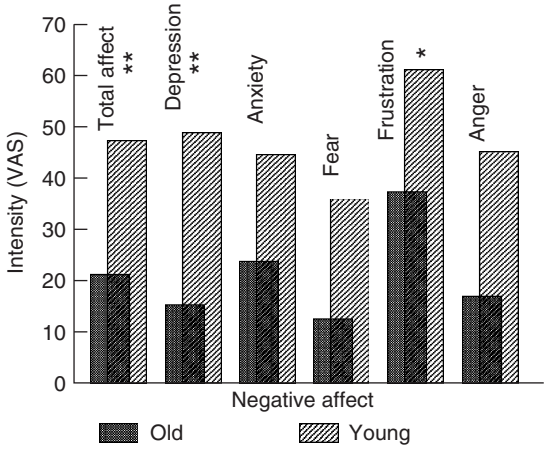

Figure 5 Stage 2 pain affect in younger and older chronic pain patients (see **Figure 1** and **Table 1**). Stage 2 pain affect is defined here as depression, anxiety, fear, frustration, and anger specifically related to the chronic pain. Total affect is the sum of the individual domain-specific affect ratings. Ratings were made on 150-mm visual analog scales (VASs) for each emotion. VASs were labeled 'no depression' (or anxiety, etc.) on the left and 'the most extreme depression imaginable' (or anxiety, etc.) on the right of the VAS. Care was taken to ensure that patients were rating their mood or affect specifically related to their chronic pain. These results indicate that domain-specific affect related to chronic pain differs with chronological age in adults and is not due to age differences in pain intensity or immediate unpleasantness of pain (stage 1 pain affect, in **Figure 1** and **Table 1**). Pain ratings made on the Virginia Commonwealth University Pain Inventory. Reproduced with permission from Harkins SW, Price DD, Bush FM, and Small R, (1995) Geriatric Pain. In: Roy R (ed.) *Chronic Pain in Old Age*, pp. 127–163. Toronto: University of Toronto Press.

changes in cognitive appraisal. Such a change in the meaning of a pain, across a lifetime, likely accounts for the reduction in stage 2 pain affect in elderly chronic pain patients discussed below (see **Figure 5**).

3. *Secondary affective component of pain – Stage 2 pain affect*: The characteristics and factors influencing stage 2 pain affect (**Figure 1**) are summarized in **Table 2**. As indicated, this secondary affective component of pain is a property of the suffering that accrues to a chronic pain. It is the distress associated with a threat to the intactness of the individual. This stage 2 pain affect is not a component of experimental pain for obvious reasons. It must be, therefore, studied in the real world in relation to the stress and suffering associated with a pain problem.

There have been no systematic studies of this dimension of pain in the elderly. Preliminary evidence (**Figure 5**) indicates that the older chronic pain patients report less stage 2 pain affect compared to younger chronic pain patients. This occurs even when the intensity and stage 1 pain affect are identical in younger and older chronic pain patients and suggests that there is a difference in meaning of the pain to younger compared to older chronic pain patients.

Special Considerations in Assessment of Geriatric Pain

There are a number of issues that must be considered in geriatric pain assessment. Some of these are summarized in **Table 3**. The major issues that merit attention are presence of comorbidities, mental status, depression, limitations in ADLs, medications, and the importance of family and other support systems (*see* Depression; Social Networks, Support, and Integration).

Eighty percent of the elderly have at least one chronic, degenerative process. Many of these degenerative processes predispose one to chronic pain (e.g., osteoarthritis, osteoporosis, parkinsonism-type movement disorders, non-insulin-dependent diabetes mellitus). Additionally, these conditions exist in the presence of acute and other chronic morbidities that may interact with the pain-related degenerative disease.

An aspect often overlooked is the *functional* consequence of the pain in the older person. Older persons may have several limitations affecting their daily activities, and the addition of pain may accentuate this. The elderly have less reserve capacity to adapt to functional stresses than do healthy young persons, and the consequence of pain on functional status may be very severe in an older person. The clinician must also be sensitive to the perceived needs of the individuals with differing wishes for the outcome of pain treatment. A patient at the end of life may wish only to die free of pain and even be heavily sedated by the medication, whereas another patient may prize the ability to effectively communicate with loved ones and want pain medications balanced so that sedation is minimized.

In dealing with the elderly patient, there is always the recognition that adverse effects of potent medicines are commonplace, and the adage start low and go slow must guide the treatment plan.

Although intensity and frequency of chronic pains, particularly those related to the musculoskeletal system, actually increase with age, presentation of pain in the very old is frequently characterized by multiplicity (multiple overlapping signs and findings), duplicity (unusual symptom presentation – particularly for acute pain of recent origin), and chronicity (new pains are especially suspicious in the elderly).

Mental status represents a challenging issue for pain assessment in the elderly. Between 50 and 60%

Table 3 Special considerations in geriatric pain assessment

1.	General considerations a. Recognize that age itself does not reduce pain sensitivity. b. Recognize that there is no evidence that age, per se, influences qualitative properties of pain. c. Recognize the importance of encouraging patient to discuss the pain.
2.	Comorbidity: Illness and symptom presentation in the elderly, particularly the frail and the old-old, is often characterized by multiplicity, duplicity, and chronicity.
3.	Mental status: Assess for cognitive impairment: Dementia of the Alzheimer's type, pseudo-dementia secondary to depression, multi-infarct dementia. Refer if necessary.
4.	Depression: Pain is likely a major source of depression in the elderly.
5.	Activities of daily living (ADLs): Differentiate between limitations caused by non-pain-related dysfunction and limitations in activities due to the fact that their performance is painful. Pain-related dysfunctions and limitation in ADLs is likely a significant source of depression in the old.
6.	Medications: Assess all current and recent medications: (look in the 'brown bag of pills'). Start low and go slow.
7.	Family and social support systems: Maintain these systems in the physically or mentally impaired elderly.

of older individuals in long-term care settings have a dementing illness. It is also estimated that up to 40% of community-dwelling individuals 80 years of age and over score in the at risk for dementia range on mental status examinations. Social skills may be well maintained and the presence of a possible dementia may only become suspected upon specific mental status evaluation. Screening instruments for evaluation of mental status exist, but because chronic pain reduces cognitive abilities, norms for such instruments are needed for older chronic pain patients.

Assessment of pain in patients with a clinical diagnosis of DAT represents a special challenge. No studies of the magnitude of this problem or the best methods for assessment of pain in dementia patients have been made. More is known about pain assessment and control in the very young than in the frail dependent or cognitively impaired elderly.

Summary and Conclusion

Four factors were identified that may influence the perception of and reactions to pain across the life span. These included changes in receptors for pain, changes in primary nociceptive neurons, changes in central mechanisms subserving pain, and psychosocial influences. The information summarized indicates limited effect of age on perceived intensity of acute, superficial pain. This would suggest that changes, at least in cutaneous pain receptors, primary nociceptive afferents, or central mechanisms subserving pain sensory processes, are not dramatically changed with age. The same cannot be said for deep or referred pains. As the mechanisms of pain from the viscera, joints, and muscle are better understood, control of pain associated with acute deep tissue injury and chronic degenerative processes in the elderly will improve.

The primary affective response (stage 1 pain affect) to pain does not change with age. Stage 2 pain affect is less in older compared to younger chronic pain patients (**Figures 1** and **5**). This likely reflects experience of the patient with this or a similar pain as well as age–cohort effects.

The properties of *presbyalgos* are defined more by similarities between younger compared to elderly individuals (**Table 2**). There is an increase in chronic pain in the old, and this is associated with greater pain intensity in the community-dwelling population, but not necessarily the pain clinic population, which is likely the result of self-selection and referral filters.

Considerable care must be exercised in evaluation and treatment of the older patient with significant comorbidity, particularly the metabolically compromised. Assessment of pain in the old-old and the frail individual is a particular challenge, which is made even more difficult if there is evidence of a dementing disorder. It is unfortunate that the very old, the frail elderly, the dementia patient, and the cognitively intact but physically challenged because of pain have not been systematically evaluated for pain and pain control. Considerable unnecessary discomfort, pain, and suffering currently exist in these subpopulations of geriatric patients.

See also: Body: Composition, Weight, Height, and Build; Depression; Hearing; Pharmacology; Social Networks, Support, and Integration; Touch and Proprioception; Vision.

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Parkinson's Disease

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Glossary

Bradykinesia – Slowness of body movement.

Deep Brain Stimulation (DBS) – Surgical treatment of choice for severe Parkinson's Disease not responsive to medication. A programmable stimulator is implanted in the chest wall to deliver continuous stimulation to the brain.

Parkinson's Disease – Progressive neurodegenerative disorder characterized by bradykinesia, tremor at rest, and rigidity.

Introduction

Parkinsons disease (PD) is a progressive neurodegenerative disorder initially described in 1817 by Dr. James Parkinson in "An Essay on the Shaking Palsy." PD is characterized clinically by the asymmetric and slowly progressive onset of parkinsonism benefiting from dopaminergic medication, and pathologically by the loss of dopaminergic cells and occurrence of Lewy bodies in the substantia nigra and specific brain stem areas. Typically, PD presents in the 60s with a slowly progressive bradykinesia (slowness) tremor at rest, and rigidity affecting one of the limbs, that benefits from dopaminergic medication, in the absence of atypical features (i.e., falls, dementia, or autonomic features early in the course of the disease). The prevalence of PD is 200–300 cases per 100 000 people, and in the United States about 1 million persons are affected. The annual incidence is approximately 20 new cases per 100 000 people, and about 60 000 Americans are diagnosed with PD each year. The likelihood of developing PD increases with age. PD typically develops in the 60s, but can occur at younger ages. Approximately 10% of all patients develop symptoms before age 40. PD is usually a sporadic disease but is hereditary in 10% of the patients. Men are slightly more frequently affected than women.

Etiology

PD is a neurodegenerative disorder affecting the basal ganglia circuitry and is unique in that most of the motor symptoms result from a single neurotransmitter deficit that is due to a loss of dopaminergic neurons in the substantia nigra pars compacta. When PD is clinically manifest, about 70–80% of the nigrostriatal neurons cease functioning. However, at later stages, most symptoms in PD (i.e., loss of balance, cognitive, autonomic and sleep disturbances) are due to non-dopaminergic neuronal degeneration. The cause of neuronal loss in sporadic PD is not clear and is likely a mix of genetic, environmental, and biological factors combined with the aging process, but PD can also be familial.

Genetics

Several gene mutations have been shown to cause PD, but they account for a small minority of patients and have not been found in most individuals with sporadic PD. Epidemiological studies indicate a

genetic contribution to the occurrence of sporadic PD. The World War II Veteran Twins Registry study shows that genetic factors play a role in sporadic PD when the disease manifests at or before age 50. Using positron emission tomography (PET) with ^{18}F-DOPA and longitudinal evaluation, 75% concordance of PD has been demonstrated in monozygotic twins versus 22% in dizygotic twins. Lazzarini et al. found in a New Jersey study that the chance of having PD by age 80 was estimated to be 2% for the general population, about 5–6% with an affected parent or sibling, and 20–40% if both a parent and sibling were affected.

There are now 11 PARK loci, each representing a genomic region linked with varying degrees of evidence to PD-like disorders (**Figure 1**). PARK-1 presents with a familial autosomal dominant PD due to mutations in the alpha-synuclein gene on chromosome 4q21.3-23. Alpha-synuclein is normally a soluble protein, but in PD it aggregates to form insoluble fibrils that are the primary structural component of the neuronal Lewy body inclusions. Putative mechanisms by which the mutated alpha-synuclein causes PD include mitochondrial damage, impaired protein disposal, and toxic build-up of protein leading to cell death.

PARK-2 presents as an autosomal recessive trait due to a gene mutation on chromosome 6q25.7-27. PARK-2 is a common genetic cause of PD but still accounts for less than 1% of all cases. The gene

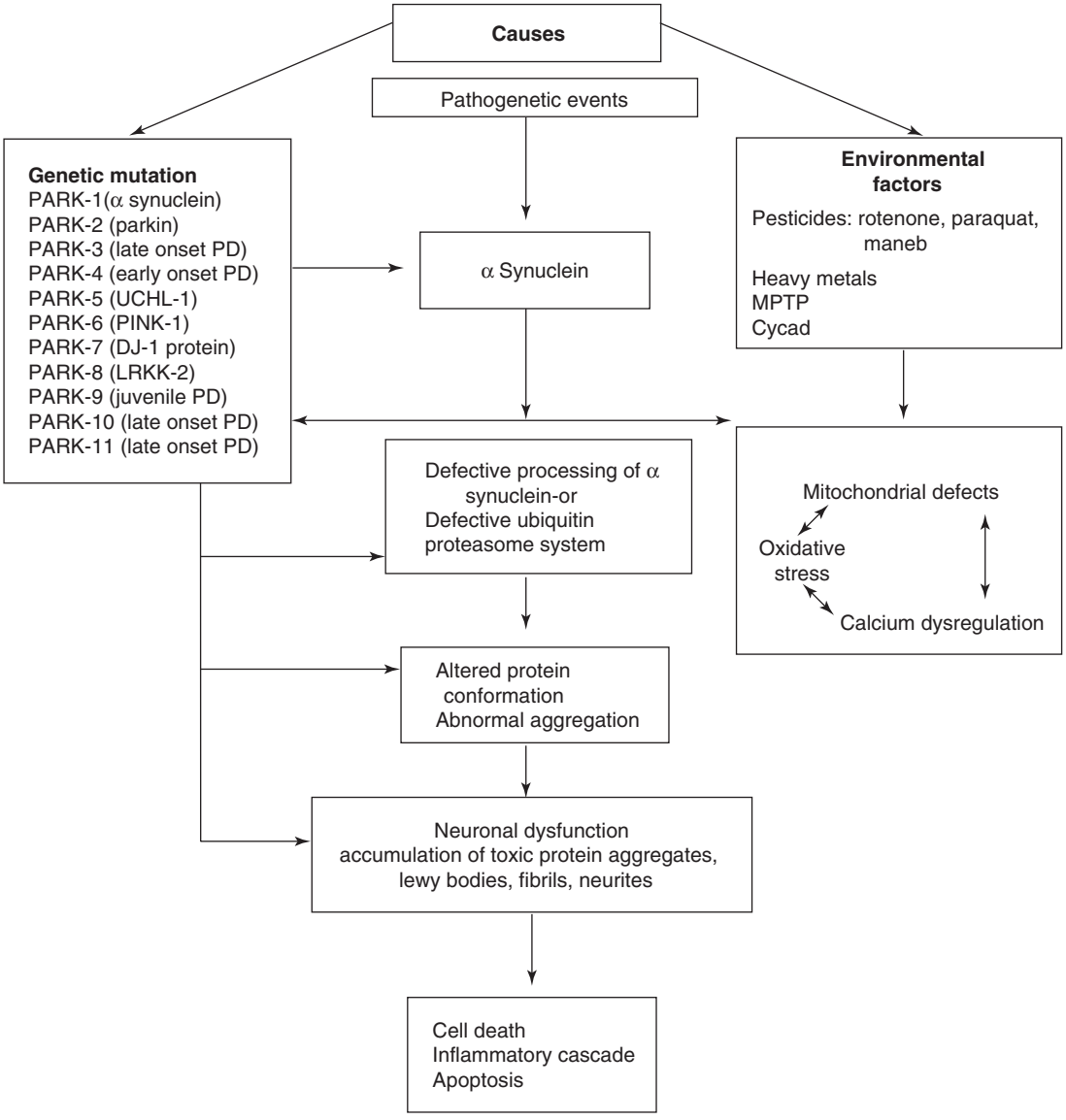

Figure 1 Pathogenesis of Parkinson's disease.

product, the protein Parkin, is a part of the ubiquitin-proteasome system, which breaks down defective proteins in the cells. Patients with the Parkin gene mutation have a young-onset PD, with symptoms beginning usually in the fourth decade of life. Those with the Parkin mutation in just one copy of the gene have a higher risk of getting PD as they get older than those without the mutation. Parkin accumulates in Lewy bodies and may be important in both inherited and sporadic forms of the disease.

PARK-3 is due to an autosomal dominant trait and a gene mutation on chromosome 2p13. Patients with PARK-3 have a relatively late age of onset, much like sporadic PD, but with rapid progression. PARK-4 is due to an autosomal dominant trait and is due to a gene mutation on chromosome 4p15. Patients present with an early-onset PD with rapid progression, autonomic dysfunction, dementia, and postural tremor. PARK-5 is an autosomal dominant trait due to a mutation in the ubiquitin carboxy-terminal hydrolase L1 (UCHL1) gene on chromosome 4p14-16.3. UCH-L1 is an important member of the ubiquitin-proteasome system that performs ubiquitination, a process that tags proteins for breakdown and is critical for the proper handling of misfolded proteins. PARK-6 is caused by mutations in a gene located on chromosome 1p36 for a mitochondrial kinase (PTEN-induced kinase 1 [PINK1]). It has been identified in several families with autosomal recessive PD of early onset and slow progression. PARKm-7 is a rare form of autosomal recessive young-onset parkinsonism due to mutations on chromosome 1p 35-36 within the gene encoding DJ-1, a 189-residue protein.

PARK-8 is the most frequent genetic cause. It has been identified in families with autosomal dominant late-onset PD and is due to mutations in the leucine-rich repeat kinase 2 gene (LRRK2, protein product dardarin), located on chromosome 12p11.2-q13.1. LRRK2 mutations have also been found in sporadic PD cases and are significantly more frequent in the Arab and Jewish population. PARK-9, due to a gene mutation on chromosome 1p36, presents as an autosomal recessive early-onset juvenile PD. Patients have spasticity, supranuclear gaze palsy, and dementia. PARK-10 and PARK-11 are chromosomal regions that have been implicated in families with PD; the genes are yet to be identified. PARK-10 locus on chromosome 1p has been linked to PD of late onset in Icelandic families. PARK-11 locus on chromosome 2q36-37 was identified in pairs of siblings with late-onset autosomal PD and appears to affect the susceptibility to the disease in North American Parkinson families.

Impairment in the capacity of the ubiquitin-proteasome system to clear unwanted proteins has been implicated in the cell death that occurs in PD. In support of this concept, defects in proteasomal structure and function as well as protein aggregates and increased levels of oxidized proteins are found in the substantia nigra of PD patients. Inhibition of proteasome activity in mesencephalic cultures induces degeneration of dopaminergic neurons coupled with the formation of proteinaceous intracellular inclusions.

PD patients have more mitochondrial DNA variations than patients with other movement disorders or Alzheimer's disease. Mitochondrial DNA mutations as the cause of PD have been actively investigated in families with maternal inheritance of PD, and potentially important mutations in the genes ND2, ND4L, and ND5 are associated with an increase risk of PD. The age at onset of PD has wide variability (even within the same family), ranging from juvenile to very late (80s to 90s), with average age at onset of 60 years. The gene for brain-derived neurotrophic factor (BDNF) may also influence PD onset age in familial PD. The gene GSTO-1 and the adjacent gene, GSTO2, appear to affect the age at onset for PD and Alzheimer's disease.

Environmental Factors

Environmental toxins, infections, and other triggers can provoke excessive production in the body of oxygen free radicals, damaging particles that may play a major role in the neuronal degeneration leading to PD (**Figure 1**). The toxin MPTP (1-methyl-4-phenyl-1,2,5,6-tetrahydropyridine), a contaminant of street drugs, has a breakdown product (MPP+) that is toxic to dopaminergic substantia nigra neurons and produces a severe, permanent parkinsonian syndrome. The relative risk of PD is higher in industrialized countries and in farmers and other agricultural workers. Rotenone, a common organic chemical in pesticides, may induce oxidative injury that targets dopaminergic, cholinergic, and GABAergic neurons. In rats, chronic rotenone exposure leads to pathological, biochemical, and behavioral features seen in PD and in atypical parkinsonian disorders. The herbicide paraquat and the fungicide maneb and their combination can lead to an irreversible and progressive dopaminergic neurotoxicity in mice. Many toxins, including MPTP and rotenone, can affect mitochondrial complex I and increase the production of free radicals. Neurotoxins in flour from cycad plants in Guam can (when fed to mice)

lead to behavioral changes and neuronal loss much like those seen in PD.

Biological Factors

Aging Process Aging is the most important risk factor for PD. The frequency of PD increases markedly with age in people older than 50. Dopaminergic neurons in the substantia nigra show about 20% cell loss in normal aging, whereas in PD more than 60% of these cells may die before the disease becomes clinically evident. Changes associated with normal aging may interact with the pathogenic processes of PD and lower the threshold for symptom expression.

Apoptosis In PD, there is some evidence that there is abnormal neuronal apoptosis. Three molecules are critical in the development of inherited PD – parkin, alpha synuclein, and ubiquitin, which all interact in the normal brain. Parkin normally causes alpha-synuclein to bind ubiquitin, which then triggers apoptosis, causing this compound to self-destruct. In the PARK-2 variety of inherited PD, Parkin is abnormal and fails to bind alpha-synuclein to ubiquitin. Apoptosis does not take place, and alpha-synuclein accumulates in Lewy bodies.

Complex I and Oxygen Free Radicals Some PD patients have a 30 to 40% reduction in the mitochondrial enzyme complex I, making nerve cells vulnerable to unstable oxygen free radicals that can modify alpha-synuclein and cause it to aggregate or clump together into fibrils.

NMDA Receptors In PD there are changes in the subthalamic nucleus, as glutamatergic N-methyl-D-aspartate (NMDA) receptors become constantly overstimulated and produce high levels of calcium ions within neurons. This in turn leads to a cascade of events that trigger oxygen free radicals and cell damage.

In summary, it is currently thought that PD is attributable to an interaction of genetic and environmental factors and that a combination of the mechanisms of oxidative damage, environmental toxins, genetic predisposition, and accelerated aging may ultimately be shown to cause the disease.

Pathology

The gross appearance of the brain in PD may show mild frontal cortical atrophy. On sectioning the brain stem, there is visible loss of neuromelanin pigmentation in the substantia nigra in the midbrain, which may associate with a rust color in the pars reticulata of the substantia nigra due to increased iron deposition. Histopathology reveals neuronal loss in the substantia nigra pars compacta and locus coeruleus along with compensatory astrocytic and microglial proliferation. Hyaline cytoplasmic inclusions-Lewy bodies (**Figure 2**) are found in the residual neurons in the substantia nigra, locus coeruleus, dorsal motor nucleus of the vagus, basal nucleus of Meynert, limbic cortex, and amygdala. Lewy bodies are proteinaceous inclusions often accompanied by abnormal neuritic filaments called Lewy neurites that on electron microscopy appear as densely aggregated filaments. Immunohistochemical studies show that the chemical composition of Lewy bodies is a mixture of proteins, including alpha-synuclein, neurofilament, and ubiquitin. Extensive serial studies by Braak in more than 400 autopsy brains have recently shown that there are stages in PD and that the substantia nigra is not affected initially. At preclinical stages there are Lewy bodies in the olfactory bulb and vagus nerve, whereas at later stages the cortex is affected, supporting the presence of olfactory and gastrointestinal disturbances at presymptomatic stages and dementia at advances stages.

Pathophysiology

In PD the loss of dopaminergic neurons projecting from the substantia nigra to the striatum (caudate and putamen) results in altered function of the motor striatal–pallidal–thalamic–cortical circuits that mediate normal movement, resulting in bradykinesia and rigidity. The striatum controls the activity of basal ganglia output neurons via two major routes: the direct pathway and the indirect pathway. There are at least five dopamine receptors that can be separated into two distinct families, D1 (made up of D1 and D5) and D2 (made up of D2, D3, and D4). The effect of dopamine and dopamine agonists on D1 receptors is excitatory, whereas their action on D2 receptors is inhibitory.

Direct Pathway

Striatal neurons containing D1 receptors project to the globus pallidus interna (GPi) and induce an inhibition via GABA and substance P upon the GPi neurons, which then in turn inhibit target neurons in the motor thalamic nuclei (**Figure 3**). This leads to disinhibition of the motor thalamus and to an increase in the firing rate of its cells. Activation of

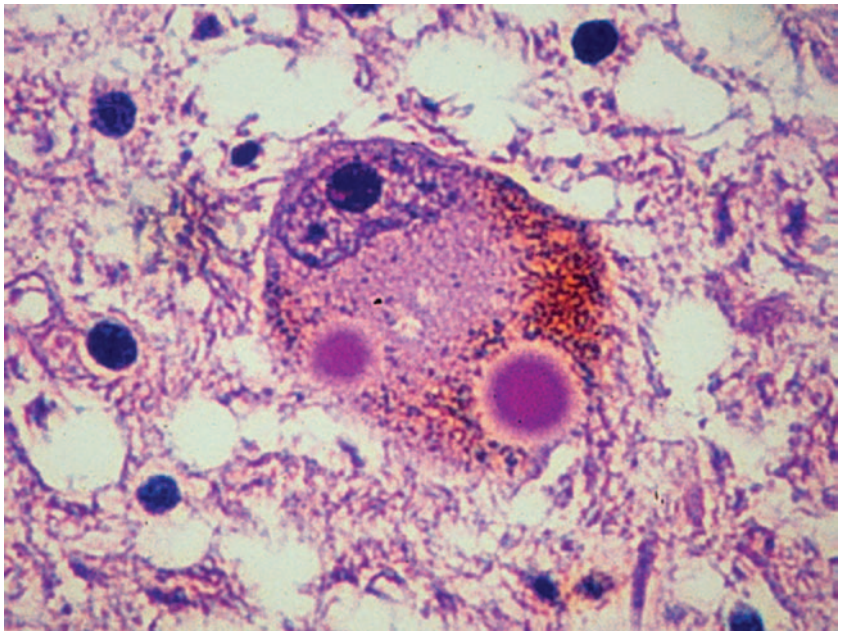

Figure 2 The Lewy body. Reproduced with permission from Mackenzie IRA (2005) Neuropathology of Atypical Parkinsonian Disorders. Litvan I, ed. In: Atypical Parkinsonian Disorders. New Jersey: Humana Press.

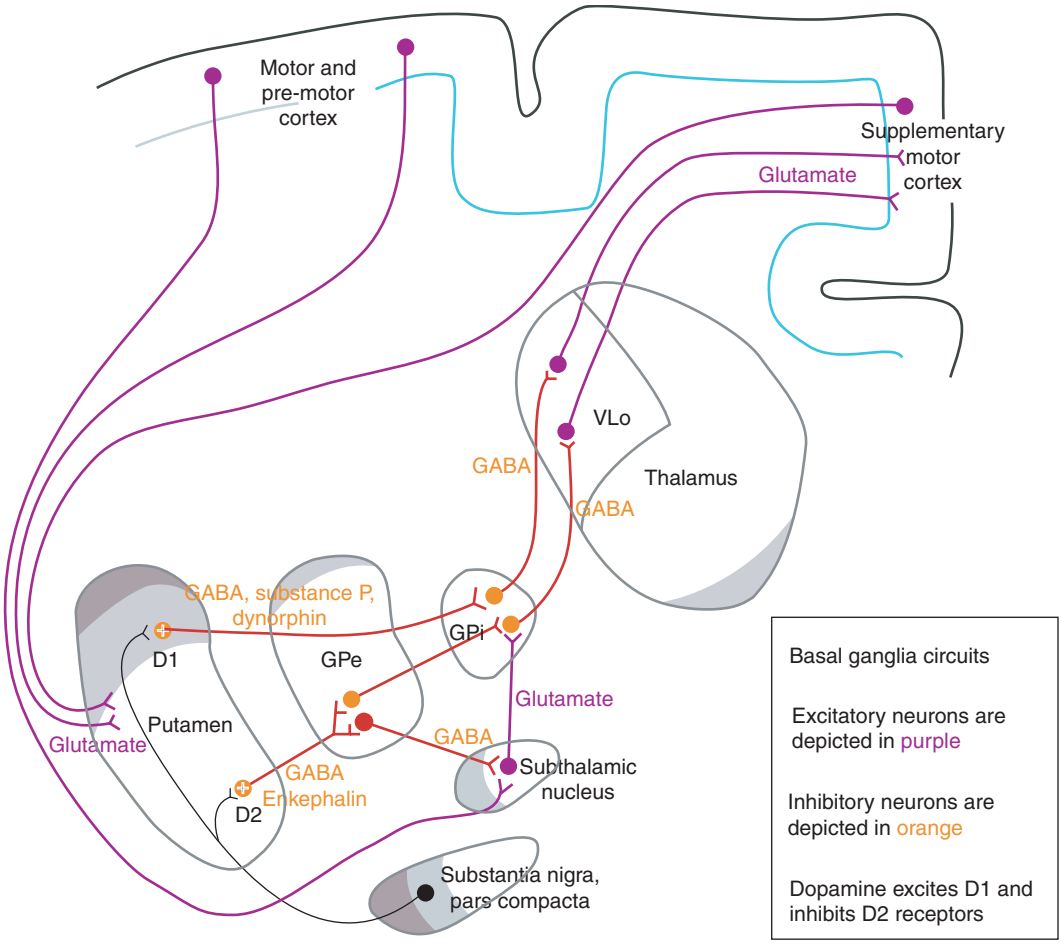

Figure 3 Diagram of basal ganglia circuitry. Courtesy of Jen-Luc Dreyer.

the direct pathway facilitates initiation or ongoing movements. In PD, the depletion of dopamine from the nigrostriatal projection to D1 receptors on the striatal neurons (excitatory) results in the direct pathway being underactive, leading to decreased firing of thalamic neurons and inhibition of initiation of movement.

Indirect Pathway

Striatal neurons containing D2 receptors project to the globus pallidus externa (GPe), which then projects to the GPi via the subthalamic nucleus (**Figure 3**). Dopamine here acts as an inhibitor of the striatum, which in turn releases GABA and enkephalin that in turn inhibit the GPe neurons, which in turn disinhibit the subthalamic nucleus. The subthalamic nucleus increased firing leads to activation of the GPi and the substantia nigra pars reticulata neurons. Since the output from the GPi to the thalamus is inhibitory, there is a reduction of excitatory thalamic input to supplementary motor areas. Thus, the indirect pathway is thought to inhibit unwanted movements. In PD, depletion of dopamine in the nigrostriatal neurons projecting to D2 receptors on the striatal neurons results in the indirect pathway being overactive. In patients with PD, ^{18}F-fluorodeoxyglucose PET studies show an abnormal metabolic brain network in the resting state characterized by relative lentiform and thalamic hypermetabolism associated with metabolic reductions in motor cortices. The combined hyperinhibitory outflow from the GPi may account for the negative symptoms of PD (rigidity and akinesia). Reduction of this excessive inhibitory outflow, by lesioning or stimulating the GPi or the subthalamic nucleus, reverses these symptoms, which is the basis of surgery in PD. Tremor activity is thought to be generated in the ventral lateral nucleus of the thalamus. On the other hand, dysregulation of the D1 pathways, in levodopa-treated patients, leads to the development of dyskinesias, a side effect of dopaminergic therapy.

Diagnosis of PD

Though the clinical features of PD are characteristic, three large clinicopathological studies show that specialists misdiagnose 25 to 40% of patients with PD in clinical practice. An early accurate diagnosis is relevant because the prognosis and treatment of patients with PD is markedly different from those with atypical parkinsonian disorders (APDs). The survival of patients with early PD is almost the same as that of the US population, particularly when appropriately treated; APD patients have a shorter survival (usually less than 10 years).

Clinical History

Patients with PD usually present over age 50 with a variety of motor complaints – tremor at rest, micrographia, slowness or poverty of movements, stiffness, or pain. Typically, the onset is insidious, and the progression is slow, affects one limb, and then spreads to the others, although the asymmetric involvement persists. Lack of associated movements and rigidity are also symptoms at onset. Tremor usually is at rest, increases in periods of anxiety, and disappears during activities or sleep. Slowness when walking may occur relatively early in the disease, but instability or falls occur later. Speech volume reduction and monotony may occur relatively early, but sialorrhea secondary to dysphagia develops at later stages. Similarly, faintness, impotence, or urinary disturbances are not early PD problems. While depression may antedate motor symptoms or associate with them, dementia is not an early feature in PD. The patient's drug treatment history should be carefully reviewed. Drug-induced parkinsonism is frequently secondary to dopamine receptor blockers used primarily as antipsychotics and antiemetics, less commonly, calcium channel blockers (e.g., flunarizine) or cardiac antiarrhythmic agents (e.g., amiodarone).

Non-motor symptoms of PD include pain, autonomic dysfunction, depression, anxiety, dementia, and sleep disorders. Pain is a common symptom, affecting as many as 46% of patients and is often related to motor dysfunction seen in the off state. Olfactory dysfunction with a reduced sense of smell may be one of the earliest PD symptoms. Autonomic dysfunction can lead to orthostatic hypotension, erectile dysfunction, excessive sweating, constipation, and urinary disturbances but these are all late symptoms.

Depression is common and can affect up to 50% of patients at any stage of the illness. It could be both reactive as well as endogenous to the neurodegenerative process with depletion of monoamines. Anxiety (generalized or panic attacks) is also common in PD and is often related to the off state. Dementia occurs late in PD, and the overall prevalence ranges from 30–40%, but prospective studies have shown that after 8 years of follow-up, up to 80% of the patients with PD may develop dementia. Pathological studies correlate dementia in PD with a significant loss of neurons in the nucleus basalis of Meynert and loss of choline acetyl transferase as well as Lewy bodies and Alzheimer-type changes in the

cerebral cortex and limbic areas. The dementia in PD could also be due to associated Alzheimer's or vascular diseases. Sleep disorders in PD include sleep-onset delay, sleep fragmentation, sleep apnea, periodic leg movements, and REM sleep behavioral disorder. Polysomnography is often required to diagnose the type of sleep disorder.

Neurological Examination

Akinesia may be assessed by having the patient tap the index finger to the thumb repeatedly or by foot tapping. Rigidity can be tested by flexion–extension of the neck and each extremity. Tremor should be assessed at rest, while performing an activity, and by maintaining a posture. Evaluation of eye movements, particularly the speed of vertical and horizontal saccades (rapid movement of the eyes between two stimuli), aid in ruling out other disorders. Parietal signs such as visual and sensory neglect can be assessed with the presentation of one or two simultaneous stimuli. Balance should be assessed with the pull test (maintaining balance while being pulled backward). The pull test is abnormal only at later stages. To effectively rule out orthostatic hypotension, blood pressure should be taken lying and after 1 and 3 min standing. The Hoehn and Yahr staging and the Unified Parkinson's Disease Rating Scale (UPDRS) are useful clinical tools for following the progression of the illness and response to therapeutic interventions.

Diagnostic Criteria

Several clinical criteria for the diagnosis of PD have been proposed. The main features required for the diagnosis of PD are the presence of akinesia (slowness, decreased amplitude of movements) associated with either rigidity or a 4–6 Hz rest tremor in addition to an excellent and maintained response to levodopa therapy and absence of atypical features. In fact, akinesia is universal in PD, but a rest tremor ultimately develops in about 75% of patients with PD. The presence of rest tremor is very highly suggestive of PD in patients with akinesia.

When a patient presents with tremor, one needs to evaluate the type of tremor (at rest, with action, postural) and determine if akinesia is present (**Figure 4**). If akinesia is not present, one should determine whether the characteristics of the tremor are those of an essential tremor (postural and with action) or cerebellar tremor (mostly an intention tremor, associated with dysmetria and other cerebellar features). If akinesia is present, one needs to determine whether the parkinsonism is due to a secondary cause (medications such as neuroleptics, amiodarone; metabolic disorders such as Wilson's disease; vascular causes; infections, etc.). If there are

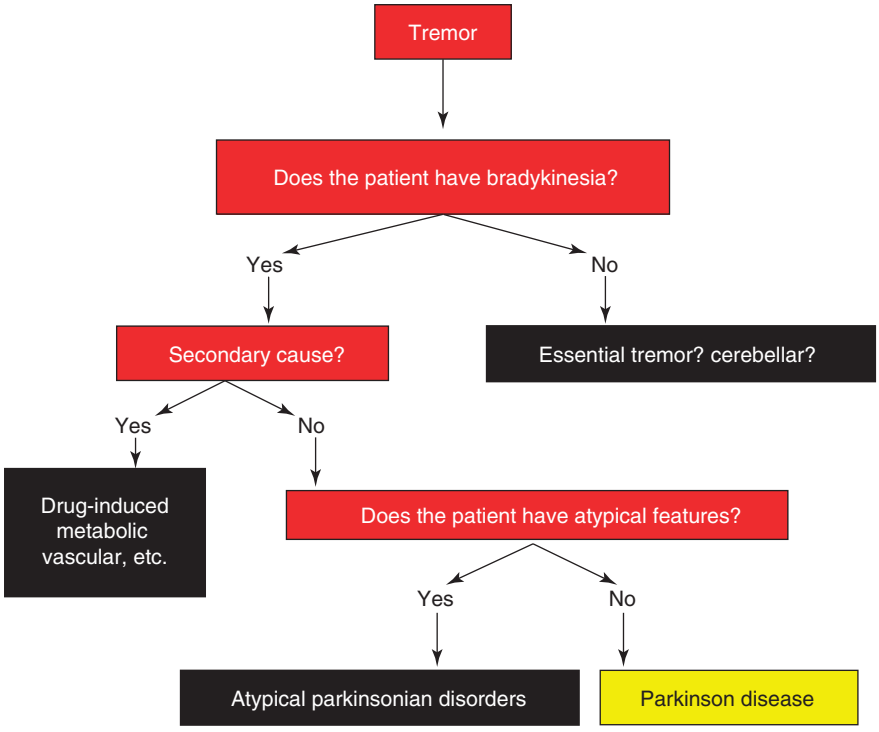

Figure 4 Diagnostic algorithm.

no identifiable causes, one should determine whether there are atypical features. Atypical features that call into question the diagnosis of PD include rapid symptom progression, early (within 3 years) postural instability, poor or transient response to dopaminergic therapy (900 mg of levodopa for at least 1 month), myoclonic jerks, supranuclear gaze palsy, early autonomic failure (i.e., orthostatic hypotension, impotence in males, neurogenic bladder), pyramidal or cerebellar signs, ideomotor apraxia, and prominent early or severe speech and swallowing difficulties. These latter features suggest an APD (progressive supranuclear palsy, multiple system atrophy, corticobasal degeneration, or dementia with Lewy bodies). If there are no atypical features, one can make the diagnosis of PD.

Laboratory Studies

The diagnosis of PD remains a clinical one. Laboratory testing is not usually needed except to rule out treatable diseases such as Wilson's disease or normopressure hydrocephalus. PD patients may benefit from a neurology consultation early in the disease to establish the most appropriate management and should always be referred when an APD is suspected.

Neuroimaging

Neuroimaging, computed tomography (CT), or magnetic resonance imaging of the brain usually aid in ruling out other diagnoses but rarely confirm PD. *In vivo* neuroreceptor imaging using radioactively labeled dopaminergic ligands in single photon emission computerized tomography (SPECT) and PET have emerged as tools to assist in the accurate diagnosis, monitor disease progression, and evaluate potential neuroprotective therapies for PD. Specific presynaptic dopaminergic markers include ^{18}F-DOPA for PET and dopamine transporter (DAT) ligands 123Iβ-CIT for SPECT. These studies demonstrate a specific pattern of asymmetric putamen greater than caudate loss of dopaminergic uptake that is progressive in PD and correlates with bradykinesia but not tremor. APDs are associated with more symmetric and diffuse reduction in uptake, affecting both caudate and putamen equally. Postsynaptic dopamine receptor imaging with IBZM-SPECT, ^{11}C-raclopride PET, and others also shows reduced uptake in APD but not in PD.

Longitudinal imaging studies estimate the onset of PD symptoms at 70–75% of normal dopaminergic activity and a preclinical phase of 4–8 years. Preclinical identification of PD may allow interventions to slow progression of the disease. PET scans are also useful to rule out PD in patients with symptoms and signs that are due to dopamine-blocking drugs.

PD also affects other neurotransmitter systems, and imaging with a serotonin receptor ligand shows reduced uptake in the cerebral cortex of PD patients with depression and a correlation with tremor scores. Ligands to SP/NK1 receptor show reduction in thalamic activity in PD patients with dyskinesia. Nicotinic acetylcholine receptors have close interactions with the dopaminergic system and play a critical role in cognitive function. SPECT imaging shows a significant decrease in nicotinic acetylcholine receptors in both cortical and subcortical regions in PD patients and is one of the substrates of the cognitive impairment in PD.

Treatment

Pharmacological Treatments

Pharmacological therapies for PD include agents that work directly or indirectly to increase the level of dopamine in the brain, delay the development of motor fluctuations, and affect other neurotransmitters to reduce some of the symptoms of PD and agents that treat the non-motor symptoms of the disease. Neuroprotective and neurorestorative therapies are still experimental.

Levodopa Levodopa was FDA approved in 1970. Dopamine does not cross the blood–brain barrier (BBB) and cannot be used as therapy for PD, but levodopa does, and its transport across the gut mucosa and BBB involves an energy-dependent carrier-mediated system. Large neutral amino acids in high-protein food compete with dopamine at both sites, and levodopa is hence best taken on an empty stomach. Levodopa is converted to dopamine in the brain and at other peripheral sites by dopadecarboxylase. Combination of levodopa with a dopadecarboxylase inhibitor, carbidopa or benserazide (these do not cross the BBB), increases the plasma half-life of levodopa from 50 to 90 min and reduces the amount required for an adequate response by 75%. Levodopa preparations in combination with decarboxylase inhibitors remain the most powerful dopaminergic agents. Initially patients have an excellent response to dopaminergic medication (honeymoon phase). Unfortunately, the short half-life of levodopa and neuronal degeneration contribute to the early development of motor fluctuations. Over time, several patterns of motor fluctuations occur with levodopa therapy. The earliest is the end of dose wearing-off phenomena in which parkinsonian symptoms occur prior to the next dose of medication.

Dyskinesias (non-rhythmic movements) may occur at the maximum effect of a dose of levodopa (peak dose), at the beginning and end of each dose (diphasic), throughout the on period (square wave dyskinesia), or they may fluctuate abruptly from immobility to severe dyskinesia (yo-yoing). Later, patients experience random on periods and off periods unrelated to dose or delayed on response to levodopa due to difficulties with gastric emptying.

Catecholamine-O-methyltransferase (COMT) is an enzyme that degrades dopamine by methylation predominantly in peripheral tissues. Two Catechol-O-methyl transferase-inhibitors (COMT-Is) are currently available for use as adjunctive therapy in PD patients who have developed motor fluctuations with inhibitors wearing-off phenomena. Tolcapone is the more potent of the two, but its hepatotoxicity has restricted its use. Entacapone has a dose-dependent effect on COMT activity. It does not cross the BBB and exerts its effect in the periphery. It also reduces homocysteine plasma levels, which could provide a mechanism to reduce cell death in PD. Currently, the combination levodopa–carbidopa–entacapone is particularly indicated for the treatment of wearing-off phenomena.

Extensive research shows that motor fluctuations can be delayed by the use of continuous dopaminergic stimulation, which is the current standard of treatment for PD. Experimental evidence in animal model studies suggests that early treatment with levodopa–carbidopa–entacapone may substantially ameliorate the incidence of motor fluctuations. Although one study showed that there were no differences between immediate release and controlled release (CR) levodopa with regard to development of motor fluctuations (continous release (CR) first study over 5 years), the controlled release doses in the study were administered only twice a day, thereby not fulfilling the principle of continuous dopaminergic stimulation.

Since immediate-release levodopa leads to the earlier development of motor fluctuations, it is not currently indicated as a first treatment in young patients with PD who tend to easily develop dyskinesias. Disease progression with loss of nigrostriatal neurons and the short half-life of dopaminergic agents are the cause of motor fluctuations, and delaying levodopa therapy may delay motor fluctuations, but once motor fluctuations are present they occur with any treatment.

Despite the evidence that levodopa is toxic in cell culture studies, there is no evidence of neurotoxicity in human or animal studies. In the ELLDOPA study, the clinical outcomes indicate that levodopa is effective in a dose-dependent manner in overcoming the signs and symptoms of PD; the drug does not worsen or hasten disease progression, but rather may slow down the rate of the disease. However, a β-CIT SPECT substudy showed that levodopa may cause a more rapid decline in the integrity of the dopamine transporter located in the nigrostriatal nerve terminals in the striatum. Further studies are needed to better understand these findings.

Dopamine Agonists Dopamine agonists, unlike levodopa, do not need to be metabolized to reach neurons. They delay the development of motor fluctuations, but are less potent and have more side effects (hallucinations, orthostatic hypotension, edema, sleep attacks, pathological gambling) than levodopa. There are two major groups of dopamine agonists: ergot derivatives (bromocriptine, cabergoline, pergolide) and non-ergot derivatives (pramipexole, ropinirole). Ergot compounds can lead to pleural, retroperitoneal fibrosis and heart valvular restrictive disease.

Apomorphine is a short-acting potent D2 agonist with high D1 receptor affinity and emetic properties. A subcutaneous preparation is FDA approved as rescue medication in patients with unpredictable off episodes, but this therapy requires prior treatment with an antiemetic drug (i.e., trimethobenzamide, domperidone). Subcutaneous administration of apomorphine has been found to have long-term efficacy in patients treated for as long as 8 years.

Bromocriptine is a partial D2 agonist, mild adrenergic agonist, with a mild D1 and serotonin antagonist properties. A number of studies have demonstrated that in the treatment of early and also advancing PD, bromocriptine is beneficial in improving disability and delaying motor fluctuations.

Cabergoline, a long-acting, more expensive, once-daily dopamine agonist, has been shown to improve motor scores and reduce levodopa dose in early and advanced PD. It has an efficacy similar to bromocriptine, but more side effects (dyskinesia and confusion). Currently, it is not FDA approved for use in PD.

Pergolide has high D2 affinity and mild D1 agonist and alpha-adrenergic activity, and has 10 times the potency of bromocriptine and similar side effects. Pergolide has been demonstrated to be effective in both early- and late-stage PD in several trials and superior to bromocriptine in regard to improvements in motor function and disability. A more recent PELMOPET trial compared pergolide to levodopa and found motor complications and dyskinesias to be three times more frequent in the levodopa-treated patients; reduction of ^{18}F-DOPA uptake on PET scans was less in pergolide-treated patients. However, pergolide frequently induces heart valvular

restrictive disease and should be avoided or used with caution.

Pramipexole is a synthetic dopamine agonist active at the D2 receptor with affinity for alpha- and beta-adrenoreceptors, acetylcholine, and serotonin receptors. A number of studies have shown the efficacy of pramipexole in PD. In levodopa-treated patients, the use of pramipexole resulted in significant benefits in activities of daily living, motor scores, off time, and levodopa dose reduction. Side effects are similar to other dopamine agonists; unexpected sleep episodes and pathological gambling were also reported side effects. The CALM-PD study using pramipexole showed significantly less motor fluctuations as compared to levodopa, but levodopa had better efficacy in reducing PD clinical scores. The SPECT imaging studies showed a 40% reduction in the rate of loss of dopamine transporter, suggesting a neuroprotective effect.

Ropinirole has affinity for D2 receptor and is effective in early and advanced PD. The REAL-PET study in early PD showed that ropinirole-treated patients at 5 years had significantly less dyskinesias than those who received levodopa. The PET studies showed that ropinirole-treated patients had significantly less reduction in ^{18}F-DOPA striatal uptake over 2 years as compared to the levodopa-treated group. The CALMPD and REALPET studies have suggested a neuroprotective effect for DAs; however, there may be alternative explanations for this observed effect.

Rotigotine, a novel dopamine agonist delivered by the transdermal route, has been demonstrated to be safe and effective in Europe and is pending FDA approval. In PD patients significant reduction in levodopa dosage was recorded at the two highest daily dosage levels. Some patients receiving rotigotine were able to completely discontinue levodopa. Adverse effects were generally mild; the most common were typical for a dopamine agonist. In patients with advanced PD, transdermal routes of administration of medications such as rotigotine may be able to diminish both the peak dose adverse effects such as dyskinesia and the wearing-off fluctuations that so often develop with the more pulsatile oral drug delivery.

Amantadine Amantadine is an antiviral drug that has multiple antiparkinson mechanisms that include dopamine synthesis, reuptake inhibition and release, D2 receptor modulation, as well as glutamate blocking activity at the NMDA receptor. It has mild beneficial effects on rigidity and bradykinesia. Its reported side effects are few and include pedal edema, livedo reticularis, and cognitive changes. Its major use has been in the treatment of early PD and as an adjunctive agent in moderate PD, but currently it is mostly used in late PD as an adjunct to reduce levodopa-induced dyskinesias attributed to an effect on NMDA receptors.

Monoamine Oxidase-B Inhibitors (MAO-BI) Selegiline is a selective irreversible inhibitor of MAO-B (an enzyme involved in the breakdown of dopamine). Selegiline has mild symptomatic benefit and has been used in early PD and also as an adjunct to levodopa. It improves UPDRS scores, thus allowing reduction in levodopa dosing. It may also benefit freezing of gait, but may worsen dyskinesias. Side effects include nausea, constipation, sweating, and hallucinations. There is no evidence that its use is associated with increased mortality in PD. A new preparation of selegiline pending FDA approval, Zydis selegiline, dissolves with contact with saliva, avoiding gastric absorption, and provides high plasma concentrations.

Rasagiline is an irreversible MAO-BI five times more potent than selegiline that is also pending FDA approval. In large clinical trials, rasagiline was effective as monotherapy in early PD, as well as adjunctive therapy to levodopa in advanced disease. A disease-modifying neuroprotective effect has also been suggested in animal models of PD and in a clinical trial.

Anticholinergics A number of drugs – trihexyphenidyl, biperiden, benztropin, and procyclidine – were used to treat PD prior to the advent of levodopa and dopamine agonists. They have troublesome central and peripheral anticholinergic side effects, especially in the elderly. They have a beneficial effect in tremor and dystonia in PD mediated through the central muscarinic acetylcholine receptors. Currently the use of anticholinergics is mainly to treat severe tremor in young-onset PD.

Non-motor Symptoms of PD Pain may be due to dystonia and responds best to optimization of dopaminergic medications to reduce off time. Orthostatic hypotension can be treated with compression stockings, by switching dopamine to levodopa preparations, or by adding fludrocortisone or midodrine. Nocturia and urgent micturition require a urological evaluation, as they may be secondary to a neurogenic spastic bladder that may respond to oxybutynin or tolterodine, to a neurogenic atonic bladder, or to obstructive causes such as benign hypertrophy of the prostate. Sildenafil may be useful for erectile dysfunction. Depression can be treated with selective serotonin reuptake inhibitors (SSRIs). Anxiety related to off periods can be treated by tailoring

dopaminergic drugs, but also improves after deep brain stimulation; generalized anxiety can be treated with alprazolam, gabapentin, or SSRIs. The symptoms of dementia in PD may respond to anticholinesterase inhibitors such as rivastigmine and donepezil, the former is FDA-approved for this use.

Surgical Treatments

The early brain operations for PD were pallidotomy and thalamotomy, which destroyed parts of the globus pallidus and thalamus, respectively. These procedures were irreversible and often led to complications. In recent years, deep brain stimulation (DBS) has been found to mimic the effects of pallidotomy and thalamotomy and has now replaced these procedures as the surgical treatment of choice for PD. These procedures are usually reserved for severely afflicted PD patients who have not had adequate relief from medications. DBS is much safer than pallidotomy or thalamotomy because the stimulation can be adjusted to match the patient's needs and turned off if adverse events occur. DBS leaves electrodes in the brain connected by wires (tunneled under the skin in the neck and scalp) to a programmable stimulator implanted in the chest wall to deliver continuous stimulation. The stimulator can be turned on and off by a magnet waved over the surface. Batteries in the chest wall can be replaced as needed, generally after 5 years. The exact mechanism of action of DBS is unknown. It is postulated that high-frequency stimulation may block neuronal output from the stimulated site or that stimulation changes the irregular neuronal activity to a tonic activation pattern.

Adjusting the stimulator and medications after electrode implantation is a major time commitment on the part of the neurological team and patient. The maximum effect of the procedure is achieved once that adjustment occurs, which may be weeks or even months after the procedure itself. Risks for DBS procedures include surgical risks (hemorrhage, infection) as well as hardware complications. These include leads breaking, electrode malfunction, stimulator failure, and battery failure.

Thalamic DBS is primarily effective against tremor but is not commonly indicated in PD. Bilateral procedures have a higher risk of adverse effects. DBS of the subthalamic nucleus has become a major procedure of choice for control of PD, but its preeminence over GPi DBS is being questioned. Both lead to improvement of all major motor features of PD, with improvement of motor scores of 40 to 60% in the off state and 10% in the on state that last for several years on follow-up. Levodopa dosage can be reduced typically around 30%, with resulting improvement in dyskinesias. Bilateral procedures appear to be superior to unilateral, with only a slightly increased risk of complications. F-DOPA PET has shown that DBS does not stop the continuous decline of dopaminergic function in patients with advanced PD. The rates of progression in patients with subthalamic nucleus DBS were within the range of previously reported data from longitudinal imaging studies in PD.

Exclusion criteria for DBS include age greater than 75 years, presence of dementia, significant cognitive abnormalities, or behavioral abnormalities. As DBS has become more common, rare but serious neuropsychiatric adverse events have been increasingly reported. Onset or worsening of depression may occur postoperatively in a small percentage of patients, often in those who were at increased risk before the procedure. Suicide, a well-known risk in depressed patients, has been reported in a handful of patients. Pre-operative neuropsychiatric evaluation and postoperative follow-up is a critical part of patient care.

Non-pharmacological Treatments

A wide variety of problems in PD may respond to non-pharmacological treatments. In all cases, an individualized approach is needed to identify the problems and determine a treatment plan. Multiple members of the treatment team, physical therapists, occupational therapists, speech-language pathologists, gerontologists, neurologists, psychologists, and others, may be involved. Effective treatment may reduce the need for medications and improve quality of life.

Motor, balance, posture, gait, and mobility can respond to physical therapy, occupational therapy, adaptive equipment, and home and workplace modification. For speech, several PD voice-training programs to increase voice volume, use of shorter sentences, breathing exercises, and range-of-motion exercises are useful. Sialorrhea can be reduced by consciously swallowing more often or by small doses of anticholinergics or injection of botulinum toxin into the salivary glands. Management of swallowing difficulties includes the periodic performance of modified barium swallow evaluations with videofluoroscopy to identify the specific disturbances. Dietary changes such as instruction to take smaller bites and to completely empty the mouth before taking the next bite, thickening liquids, and eating softer foods may be indicated at different stages. Constipation can be reduced by a good bowel regimen, increased fluid intake, a diet rich in vegetables and fruits, use of stool softeners, and increased dietary and/or supplemental fiber.

Experimental Therapies

Several experimental therapies are being tried for PD and need further research. They include Coenzyme Q10, anti-inflammatory drugs, glial cell-derived neurotrophic factor (GDNF), gene therapy, and cell transplantation using fetal substantia nigra as well as retinal pigment epithelial cells.

In recent studies stem cells have been shown to be capable of differentiating into dopaminergic neurons that provide benefits following transplantation in animal models of PD. Stem cells offer great promise as a therapy for PD; however, cell survival and behavioral responses are limited and further research is required.

Prevention

Primary prevention of PD includes reduction of identifiable environmental toxins. Genetic counseling in the small proportion of familial PD is helpful.

The regular use of ibuprofen may delay or prevent the onset of PD. A recent study on the use of nonsteroidal anti-inflammatory drugs and PD risk found that individuals who regularly used ibuprofen had about a 35% lower risk of developing PD than nonusers.

Large prospective epidemiological studies have linked the consumption of coffee to a reduced risk of subsequently developing PD. Caffeine consumption is associated with a reduced risk of PD in men but not in women. Caffeine as well as more specific antagonists of the adenosine A(2A) receptor has also been found to attenuate neurotoxicity in a mouse model of PD. The convergence of these epidemiological and laboratory data supports the possibility that caffeine may reduce the risk of developing PD. In addition to possessing neuroprotective potential, caffeine and adenosine A(2A) antagonists are being studied as a symptomatic antiparkinsonian therapy.

Conclusions

The prevalence of PD is likely to increase as the aging population increases in developed and developing countries. The advances in molecular and genetic research indicate that PD is likely to be a heterogeneous disorder with varying genetic predispositions and precipitated by environment, biological factors, and aging. There is an urgent need for more widespread advanced centers for the care of PD patients with trained movement disorder specialists, rehabilitation specialists, and state-of-the-art diagnostic and therapeutic modalities. The use of neuroreceptor imaging should lead to an early (preclinical) diagnosis in familial PD and allow the appraisal of potential neuroprotective therapeutic strategies. The advent and increasing availability of DBS should offer a respite for severely affected PD patients unresponsive to maximal medical therapy. More research into genetic, environmental, and biological factors causing PD may allow preventive and neuroprotective strategies to be devised to reduce the incidence of the disease.

See also: Assessment: Neuropsychological; Balance, Posture and Gait; Cell Death; Dementia; Motor Control; Neuroimaging (MRI, PET); Neuromuscular System; Neurotransmitters and Neurotrophic Factors.

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Perception

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Glossary

Perceptual Span (also called Iconic Memory) – The amount of information that can be captured at a glance and held shortly in a sensory store.

Stimulus Persistence – The afterimage that stays in our mind after having perceived an object.

Introduction

As we know from everyday experience, the use of reading glasses or hearing aids is much more common among older adults than among young adults, adolescents, or children. From early to late adulthood and into advanced old age, sensory functions and perceptual abilities show marked and accelerating decline. Perceptual declines are observed across all modalities, such as vision, hearing, touch, smell, and taste, and they progress in close interaction with age-associated changes in cognition. In light of the steady increase in life expectancy in most developed countries, a thorough understanding of senescent changes in perception is needed in order to prepare for interventions aiming at postponing or at least at attenuating their adverse effects on everyday competence.

Aging is not a unitary process but is systemic and differential in nature. Variations between and within individuals reflect interactions among factors that are biological (e.g., genetic and neuronal), environmental (e.g., support structures), and experiential (e.g., compensatory strategies and expertise). Perceptual processes connect the faculties of the mind with the external world by representing environmental stimulations transmitted through the sensory systems (e.g., bottom-up processes) in the context of higher-order cognitive operations that involve attentional control and working memory (e.g., top-down processes). Thus, the aging of perception is a complex product of age-related negative changes in both sensory and cognitive mechanisms. Accordingly, research on perception in old age requires the empirical and conceptual integration of bottom-up and top-down processes at different levels of analysis (e.g., behavioral and neuronal; sensory, perceptual, and cognitive).

This article begins by summarizing findings on sensory decline, with an emphasis on vision, hearing, and balance control. Next, it reviews the ways in which sensory changes relate to cognitive functioning in the elderly. Finally, it discusses possible mechanisms that contribute to couplings among sensory, perceptual, and cognitive declines.

Perceptual Changes in Adulthood and Old Age: A Summary

Age-related alterations are found for all senses and at all levels of processing, from changes in the retina of the eye or the cochlea of the inner ear to changes in higher cortical sensory processing areas and related perceptual phenomena. This section selectively focuses on two primary modalities – vision and hearing – and modally complex sensorimotor functions (e.g., postural control and gait).

Vision

Various aspects of the visual system deteriorate throughout the adult life span, and numerous factors contribute to this decline. The lenses, for example, become harder, denser, and more opaque, thereby increasing the scattering of light and blurring retinal images. The iris becomes less motile so that the pupil becomes smaller. In addition, the number of receptor cells on the retina also declines. This loss is more pronounced for rods than for cones, contributing to greater age-related decline in peripheral than in central vision.

At a more perceptual level of analysis, aging has negative effects on basically any aspect of visual processing. Close and distant visual acuities, for example, decline with age. After approximately age 30, the ability to resolve images into their smallest details decreases. This loss in acuity is less pronounced for large, bright, and high-contrast stimuli, and it can be corrected, to some extent, by wearing glasses or other corrective lenses. However, even with optimal optical correction, older adults continue to resolve less detail than young adults. Depth perception decreases with age, and cases of stereoblindness increase after age 75. Accommodation and light sensitivity also change with age. Young adults adapt faster to darkness and perceive stimuli much more precisely in situations of little luminance. Young adults can, for example, continue reading a book during dusk, when older adults would need to switch on a light.

Peripheral vision, or the ability to detect objects in the periphery of the visual field, deteriorates with

age, in part reflecting reductions in photoreceptor density. The scotopic rods on the periphery degenerate earlier than the photopic cones in the fovea. The resulting reductions in peripheral vision compromise everyday activities such as driving, for which stimuli in the periphery, such as a car approaching a street crossing, need to be detected in time. Motion discrimination is reduced in old age, especially among women, again with marked consequences for everyday life. For example, one must be able to estimate how long it will take an approaching car to come closer in order to decide whether to cross the street or to let the car drive by first.

Stimulus persistence, which refers to the afterimage that stays in our mind after having perceived an object, is increased in the elderly. Shorter afterimages permit faster perception of new stimuli. Stimulus persistence is assessed by the critical flicker fusion threshold, which refers to the stimulus frequencies above which flickering lights are perceived as a persistent light. This threshold decreases with advancing age, indicating reductions in the temporal resolution of visual processing. Bright and high-contrast stimuli leave a shorter afterimage and result in smaller adult age differences in stimulus persistence than less-bright and low-contrast stimuli.

Perceptual span, or iconic memory, refers to the amount of information that can be captured at a glance and held shortly in a sensory store. Young adults typically capture about nine letters of an array, and this number decreases with age. Relatedly, the area of the visual field that individuals can capture accurately at one glance, the useful field of view (UFOV), is about three times larger in young adults than in older adults. Because older adults perceive smaller chunks of an image than young adults, they also have greater difficulties in recognizing ambiguous figures.

This description of age changes in visual perception is exemplary rather than exhaustive. For instance, color discrimination and the accuracy of eye movements (e.g., saccadic accuracy) also deteriorate with age, whereas color constancy, or the ability to identify colors under different lighting conditions, remains relatively intact (*see* Vision). As a result of all these interacting sensory and perceptual changes, less and noisier information reaches the visual cortex. In conjunction with other neuroanatomical and neurochemical changes, this altered input is associated with marked age differences in brain activation patterns during visual processing. There are two main visual pathways: the ventral pathway follows occipitotemporal connections and codes for object information, whereas the dorsal pathway proceeds via occipitoparietal connections and primarily codes for information about the location or specific nature of objects. Probably in part due to aging losses in sensory and low-level perceptual aspects of vision, the specificity of brain activation in the ventral pathway coding different categories of object stimuli (e.g., faces or objects) is reduced, and task-related differences between ventral and dorsal visual processing pathways are less pronounced.

Age-related changes in visual sensation and perception impinge upon older adults' performance in perceptual and cognitive tasks that depend on processing of visual information. Some of the relevant processes include visual search, feature detection, identification of individual characters (e.g., letters or digits), and object recognition. On the one hand, declines in these basic perceptual-cognitive processes limit higher-order cognition such as perceptual and semantic binding of episodic memory traces, decision making, and response selection. On the other hand, decrements in cognitive mechanisms, such as working memory and selective attention, also influence early stages of visual processing. Perceptual processing in the elderly is particularly compromised when prior knowledge of the task environment is low, be it in everyday life or during experimentally controlled laboratory conditions.

Compromised visual abilities have negative effects on everyday competence. For instance, visual deficits increase the likelihood of risky driving behaviors. Reading and writing abilities can also be affected, which may increase the need for the help of others in filling out forms, reading street signs, and the like. Age-related visual decline also narrows the range of options for entertainment (e.g., watching a movie) and information gathering (e.g., reading a newspaper). To some extent, these negative effects of visual aging can be attenuated by wearing corrective lenses (e.g., glasses) or compensated for by relying more heavily on other senses, such as hearing, and the help of others. Note, however, that very old individuals tend to have multiple sensory impairments, which restricts the opportunity for cross-modal integration.

On the positive side, the ontogeny of the visual system is not just a story of losses, primarily because older individuals have acquired and stored a vast amount of experience with visual perceptual tasks in the course of their lives. This general experience with the visual world, as well as individuals' idiosyncratic, person-specific expertise in processing visual patterns, modulates and sometimes attenuates declines in processing. For instance, young and older adults have been found to be equally proficient in searching for traffic signs in digitized images of real-world traffic scenes, which is remarkable in light of the losses summarized previously. Most likely, everyday

life situations often provide cues such as texture and other contextual information that help older adults identify images that they would find difficult to identify without such context.

In everyday life, then, the behavioral consequences of senescent changes in visual processing at sensory, perceptual, and cognitive levels can be attenuated by the accumulation of task-relevant experience and general visual world knowledge, pointing to the need to consider interactions among top-down experiential factors (e.g., professional expertise), top-down cognitive mechanisms (e.g., selective attention), and bottom-up sensory processes (e.g., contrast sensitivity). It follows that age trends in visual processing observed with decontextualized materials in experimental settings may overestimate the extent of functional decline observed under more naturalistic task conditions. At the same time, careful assessment and possibly control of age differences in visual sensory processing are required to capture and examine the additive and interactive contributions of sensory and cognitive mechanisms to the aging of visual perception. Furthermore, in geriatric assessment, for example, when screening for Alzheimer's disease, one should be aware that decline in visual processing as well as in other sensory systems may affect the specificity and sensitivity of diagnostic procedures.

Hearing

Auditory perception also declines with advancing age. Hearing losses become noticeable at around age 30 for men and age 50 for women, possibly as a result of differential exposure to environmental noise, such as noise associated with the operation of heavy equipment. Losses are most pronounced for high-frequency tones and accelerate with age. Similar to visual perception, age-related changes in the auditory system occur at all levels of processing. In the cochlea, loss of basilar membrane hair cells and reduced neural transmission are observed. Furthermore, the cochlear wall becomes thinner. The number of neurons in the auditory nerve decreases, along with structural, functional, and chemical alterations of early auditory processing pathways. In part as a consequence of these sensory changes, the representation of sounds in the auditory cortex differs markedly by age.

Many aspects of hearing are affected by age. Hearing thresholds show a marked increase with age. Reduced hearing sensitivity at high frequencies is a good predictor for general hearing loss. Hearing loss affects psychoacoustic dimensions such as frequency discrimination (e.g., deciding whether two tones have the same pitch or not), intensity discrimination (e.g., discriminating loudness), and temporal processing. One way to measure temporal aspects of auditory processing is to assess the ability to detect gaps in a stream of auditory stimuli. Similar to critical flicker fusion in the visual modality, older adults are unable to detect short gaps between auditory stimuli that young adults notice easily, especially when the stimuli are complex. Another aspect of temporal auditory processing refers to duration discrimination, or the ability to notice differences between the lengths of two tones. Again, this ability is compromised in old age, especially with complex auditory stimuli. Finally, temporal processing also includes the ability to encode and represent the order of a tone sequence. Older adults show more difficulty than young adults in making such order discriminations. Many other aspects of hearing are also affected by age. One important example is spatial hearing or the sound localization from binaural cues (*see* Hearing).

In concert with other changes in auditory perception, age-based changes in temporal aspects of auditory processing have profound effects on speech comprehension. The increasing inability of elderly people to understand speech is by far the most important everyday implication of age-related auditory decline. Whereas speech perception is at least mildly impaired in half of the 70-to-80-year-olds, two-thirds of 80- to 90-year-olds are moderately to severely impaired, and two-thirds of individuals older than 90 years of age have moderate to severe problems in understanding speech. Difficulties in speech perception are exaggerated when background noise is high, when speech is speeded up, when many people take part in the conversation, or when the topic of conversation is complex. Again, declines in speech perception are best understood as an interaction of sensory changes (e.g., basilar membrane hair cell loss) and cognitive changes (e.g., decreasing working memory capacity). Speech is important for maintaining social contact with others. Hence, problems in understanding speech caused by declines of the auditory system can have far-reaching effects on participation in social life and psychological well-being (*see* Social Cognition). In terms of remediation in applied settings, older people's deficits in speech perception can be attenuated by providing contextual cues (e.g., explicitly naming and introducing the topic to be talked about), lowering the speed of speech production, and using well-adjusted hearing aids.

Posture Control and Gait

As a hybrid, multimodal sensorimotor function, keeping balance while standing or walking requires

online dynamic integrations of the visual, auditory, vestibular, and proprioceptive senses. All of these senses decline with advancing adult age. The standard apparatus used for assessing individuals' postural control ability is the force platform, which measures ground reaction forces and momentums of the displacements of the body's center of balance. In general, older adults sway more than young adults, particularly when the conditions of keeping balance are made more challenging (e.g., standing on a non-stable surface, receiving conflicting visual and proprioceptive sensory information, or performing a difficult concurrent cognitive task). Age-related loss of postural stability also affects gait. Walking requires not only the integration and updating of sensory and proprioceptive information, but also the execution of motor commands that are being sent to the trunk and leg muscles. Aging adversely affects all these stages of the postural control and gait system, which leads to increased demands of cognitive control for gait in the elderly.

In part, aging-related declines in postural and gait control are attributable to declines in vestibular, peripheral sensory, and muscular systems. In addition, senescent changes in several brain areas such as the cerebellum, basal ganglia, sensory motor cortex, and brain stem, as well as the parietal cortex, a brain region involved in the neural representation of the body in space, and preparatory motor attention play a role.

Similar to vision and hearing, declines in balance and gait have profound effects on older adults' everyday competence. Losing balance increases the risk for falls, which often lead to physical injuries (e.g., femur and hip fractures), with long-lasting and often irreversible effects on mobility, health, social participation, and personal well-being. Compromised balance and gait also hinder participation in social activities such as visiting relatives and friends or participating in reading clubs, thereby increasing the risk of feeling lonely and isolated. Also, the fear of falling may foster more generalized feelings of insecurity.

Various strands of research explore ways of attenuating age-related declines in balance and gait. In addition to the use of walking aids, applied bioengineering research has made use of the phenomenon of stochastic resonance, which refers to the improved detection of subthreshold signals through admixture of optimal levels of input noise to the sensory and perceptual systems. For instance, it has been shown that older adults' postural control can be improved by vibrating insoles that provide appropriate levels of subliminal proprioceptive stimulation. Related research aims at strengthening the small muscles of the joints, which are particularly relevant for maintaining balance.

Most research on perceptual aging has examined visual or auditory modalities, but performance in other sensory modalities is known to decline as well. As pointed out earlier, sensorimotor functions such as postural control and gait are among them. Other examples are olfactory and tactile information processing, with noticeable decline in middle adulthood. Furthermore, multivariate research on individual differences in perceptual aging has found that perceptual declines tend to correlate across modalities. For instance, declines in visual processing contribute to difficulties in maintaining an upright stance under challenging conditions. In addition to direct causal relations among declines in different perceptual or sensory functions, available evidence suggests that decline in top-down cognitive functions acts as a third variable that contributes to perceptual and sensory decline across a wide range of modalities.

The Link between Perception and Cognition in Old Age

The aging of perceptual abilities is embedded into sensory and cognitive changes (see **Figure 1**). Even though some aspects of intellectual functioning, such as practical and professional knowledge, are maintained or even show gains throughout adulthood and early old age, other intellectual abilities, especially those related to the fluid mechanics (e.g., processing speed, working memory, episodic memory, and reasoning), start to decline in young or middle adulthood and accelerate their decline in old and very old age.

Converging evidence from correlational and experimental studies points to an increasingly strong connection between sensory and cognitive functioning with advancing adult age. Correlations between measures of sensory functions and measures of intelligence are stronger in samples of older adults than in samples of younger adults. For instance, in one cross-sectional age-comparative study, it was found that the variance in cognitive performance shared with vision, hearing, or both was considerably larger in the older age group (see **Figure 2**). This strengthening of the connection between sensory and cognitive domains of functioning is not restricted to vision and hearing. Posture control and gait, tactile information processing, and indicators of general somatic health also are more strongly associated with measures of intellectual functioning in old age than in adulthood.

Initially, multivariate empirical evidence on cognitive-sensory correlations was based primarily on

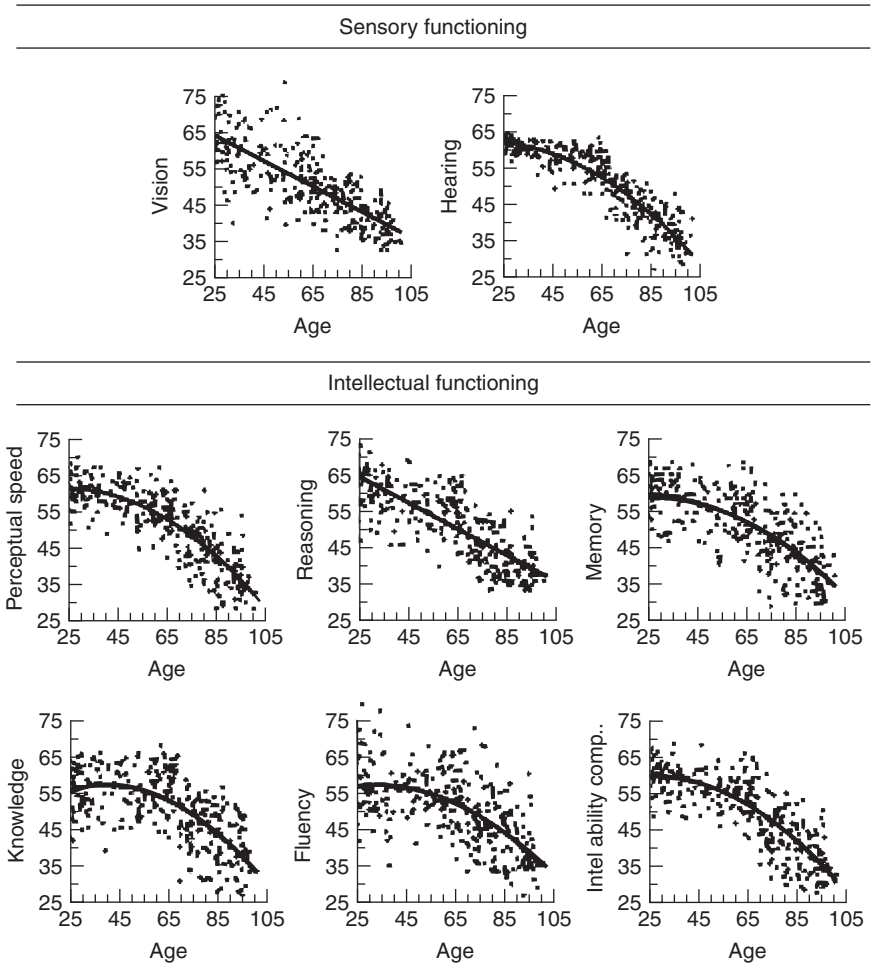

Figure 1 Cross-sectional age gradients for vision, hearing, five intellectual abilities, and the intellectual ability composite ($N = 315$, age range = 25–101 years). With respect to vision and reasoning, quadratic age trends did not differ significantly from zero ($P > 0.01$). Intel. Ability Comp., intellectual ability composite. Reproduced with permission from Baltes PB and Lindenberger U (1997) *Psychology and Aging* 12: 12–21, American Psychological Association.

age-comparative cross-sectional data, which have a number of methodological shortcomings. More recent longitudinal studies report similar, though less extreme, increments in correlations between sensory and intellectual measures. Recent analyses of longitudinal data provide more direct support for dynamic couplings between sensory and cognitive changes in old age. Applying the multivariate dual-change score models (DCSMs) developed by McArdle and colleagues to 8-year, four-occasion longitudinal change data from the Berlin Aging Study, Ghisletta and Lindenberger found that changes in vision and changes in cognition are linked to each other over time by directed effects in either direction. However, other recent analyses of multivariate longitudinal data fail to support dedifferentiation. These discrepancies may be due to measurement issues, the contribution of short-term fluctuations to longitudinal change, and sample heterogeneity. With respect to the latter, sensory/perceptual and cognitive functions may dedifferentiate in some but not all older adults.

Experimental evidence suggests that cognitive involvement in sensory and sensorimotor functions increases with adult age. A common methodological approach is a variant of the dual-task paradigm in which individuals are asked to perform a sensorimotor task (e.g., balancing, walking, or spatial navigation) while performing a cognitive task (memorizing, speech perception or production, or simple decision making) at the same time. Typically, sensorimotor-cognitive dual-task costs increase from early to late adulthood, pointing to greater online interdependence between sensorimotor and cognitive domains of functioning. For instance, in one study, young, middle-aged, and older adults were asked to memorize words while walking on a narrow track. In both task domains, dual-task costs increased with age (for memory performance, see **Figure 3**). Follow-up studies

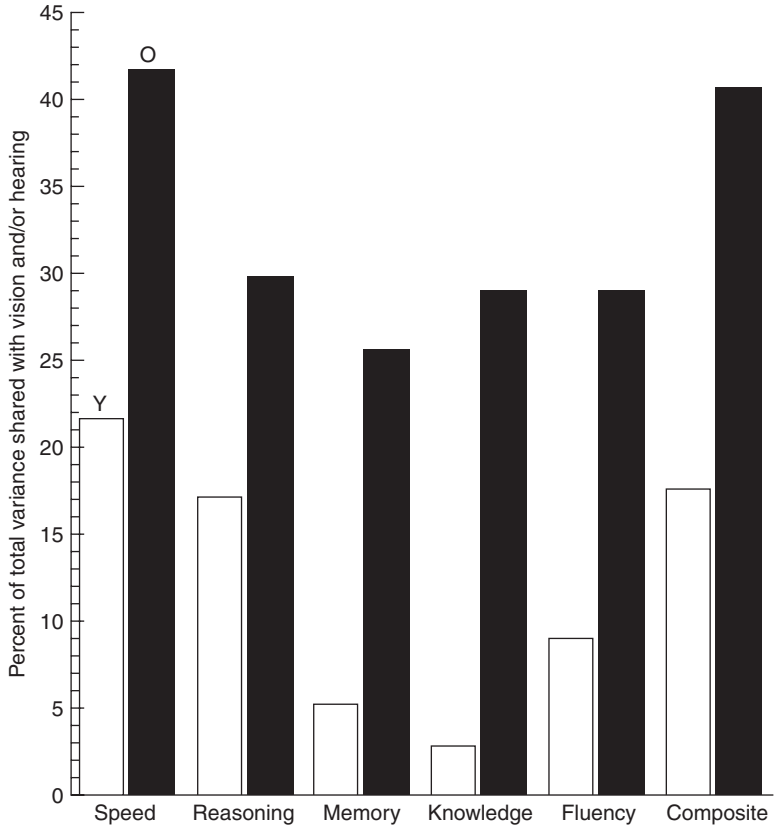

Figure 2 Amount of total variance in intellectual functioning accounted for by vision and hearing in two age groups. Bars represent the amount of total variance predicted by the main effects of vision and hearing. White bars refer to the younger (Y) sample ($N = 171$, age range = 25–69 years), and black bars to the old age (O) sample ($N = 516$, age range = 70–103 years). Except for reasoning, differences in predicted variance were significant at the 0.01 level. Reproduced with permission from Baltes PB and Lindenberger U (1997) *Psychology and Aging* 12: 12–21, American Psychological Association.

found that older individuals tend to prioritize walking as the walking tasks become increasingly difficult, presumably reflecting the adverse consequences of falling.

The finding of increasing couplings between sensory, sensorimotor, and cognitive performance has motivated researchers to design technological support structures such as hearing aids to reduce the cognitive resource load of across-domain multitasking, which is common in daily life (e.g., rehearsing a shopping list while walking on a slippery path).

Perception at the Interface of Sensory and Cognitive Aging: The Search for Systemic Explanations

Three different but not mutually exclusive explanations have been proposed for the increased coupling (dedifferentiation) of sensory and cognitive functions. First, according to the notion of sensory biomarkers, declining sensory abilities represent the first and most valid signs of behavioral and brain aging in general. Second, according to the cognitive permeation hypothesis, sensory and sensorimotor functions are increasingly in need of attentional and related cognitive resources, which themselves are declining, to attenuate the adverse consequences of sensory and sensorimotor losses. Third, according to the common-cause hypothesis, the etiologies of senescent changes overlap across sensory, sensorimotor, and cognitive domains, and this overlap in causal factors imposes increasingly severe and common constraints on sensory, sensorimotor, and cognitive aspects of behavior.

Within the sensory biomarker approach, proponents of the cascade hypothesis state that age-related losses in sensory functions temporally precede and possibly cause age-related losses in cognitive performance. More specifically, the sensory deprivation hypothesis suggests that declining sensory systems result in chronically impoverished sensory inputs, which over time alter the processing interactions between sensory and cognitive processes.

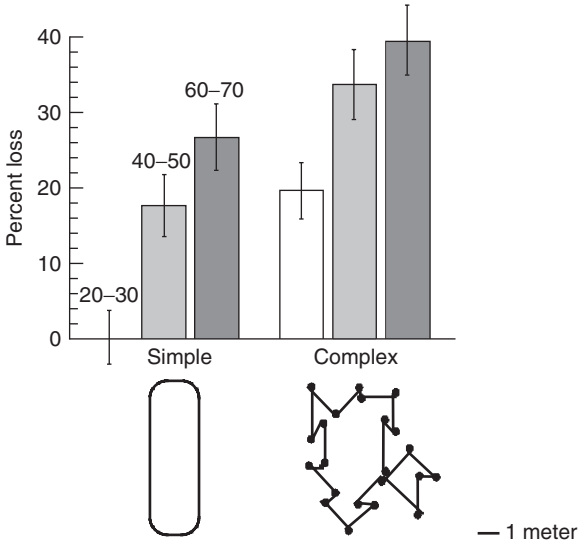

Figure 3 Dual-task costs in memory performance as a function of track and age group. Cost scores refer to the percentage of loss in serial word recall with the method of loci under walking encoding conditions (oval vs. aperiodic track) relative to the average of seated and standing encoding conditions. Middle-aged and old adults showed significantly higher costs than young adults. Error bars represent standard errors of the mean. Schematic drawings of the oval and aperiodic walking tracks are shown underneath. Error bars represent 95% confidence intervals. Adapted from Lindenberger U *et al.* (2000) *Psychology and Aging* 15: 417–436.

According to the cognitive permeation hypothesis, older adults need to invest more attentional resources into sensory and perceptual aspects of stimulus processing and sensorimotor control, which leaves less room for further cognitive processing of the same or some other concurrently executed task. Thus, sensory and sensorimotor tasks or task components that are processed in a largely automatic fashion by specialized sensory and perceptual mechanisms in younger adults are converted into cognitively demanding tasks in their own right with advancing age.

Proponents of the common-cause hypothesis underscore that the aging brain is marked by senescent changes at anatomic, chemical, and functional levels of analysis and that some of these changes have domain-general consequences that transcend the conventional boundaries between sensation, perception, and cognition. The volumes and densities of gray and white matter decline in many brain regions of the brain, though at different rates. For instance, the rate of shrinkage has been found to be larger in the prefrontal cortex and the hippocampus than in other cortical and subcortical regions. Other senescent changes include neuronal loss, loss of dendritic density, and deficient neuromodulation. Sensation, perception, and cognition depend on functional neural circuitries that overlap and interact in space and time. For instance, prefrontal circuitry is involved in attentional control during cognitive tasks and also plays an increasing role in the top-down regulation of seemingly simple sensorimotor tasks. Moreover, certain pathological alterations, such as changes in the basal ganglia and the substantia nigra in Parkinson's disease, are known to affect both cognitive (e.g., working memory) (*see* Intelligence; Memory) and sensorimotor (e.g., tremor) aspects of behavior. Milder forms of these alterations are also present in normal aging. Specifically, decrements in dopamine receptor density result in substantial changes in dopaminergic neuromodulation and related frontostriatal circuitries, with presumably widespread consequences on behavior.

Empirical support for the common-cause hypothesis can be found at different levels of analysis. The majority of findings from cross-sectional as well as longitudinal studies point to a dedifferentiation of ability structures within and across domains of functioning. Similarly, cortical activation patterns become more diffuse with advancing age, and the cortical circuitries activated during performance on different cognitive and perceptual tasks tend to show greater overlap (i.e., less specificity) in older adults than in young adults. These results can be interpreted in terms of age-associated decrements in the signal-to-noise ratio of neural processing. Li, Lindenberger, and colleagues have proposed that aging-related declines in dopaminergic neuromodulation decrease the signal-to-noise ratio of neural information processing, which in turn increases the relative contribution of random processing noise, resulting in less distinctive neurocognitive representations of environmental inputs and dedifferentiated processing pathways.

For instance, neurocomputational modeling suggests that suboptimal dopaminergic neuromodulation in simulated old neural networks reduces the activation intensity and increases stochastic activation variability in response to perceptual stimuli embedded in background sensory noise. More recent simulations of sensory detection demonstrated that both simulated young and simulated old neural networks exhibit the fundamental phenomenon of stochastic resonance, although the magnitude of the effect is smaller in old networks. Moreover, in line with recent empirical evidence, older networks actually needed more external noise to show the stochastic resonance effect.

As for the effect of dedifferentiation, computational results also indicate that suboptimal neuromodulation results in less distinctive neurocognitive representations of different stimuli or stimulus categories, as well as a greater amount of cross-process coactivation

between, for instance, verbal and spatial processes. These computational effects on stimulus dedifferentiation and process coactivation are in line with at least two lines of empirical inquiry. First, with respect to stimulus dedifferentiation, Park and colleagues examined young and older adults' brain activation patterns while perceiving visual stimuli of faces, scenes, objects, and pseudo-words. Previous research with young adults has found that faces activate an area in the temporal cortex (i.e., the fusiform face area), whereas houses and scenes activate an area in the parietal cortex (i.e., the parahippocampal place area). The results of the study by Park *et al.* show that activation patterns were less category specific in older adults than in young adults, which is consistent with the assumption of more diffuse, or less distinct, neuronal representations in the aging brain. According to a rival explanation, the elderly activate more brain areas in order to compensate for age-related losses.

Second, studies on neurocognitive aging have shown that different processes such as verbal versus spatial working memory or memory encoding versus retrieval operations, both of which involve relatively distinct functional cortical regions in young adults, tend to activate more and more similar cortical regions in older adults. Again, it is unclear whether additional activation reflects the inability to suppress competing neuronal groups and to process information in distinct ways (e.g., dedifferentiation), whether additional activation reflects compensatory recruitment of neural circuitry to compensate for aging-related losses (e.g., compensation), or whether it reflects a mixture of both dedifferentiation and compensation.

In summary, normal aging alters perceptual processing through more than one developmental pathway. Some of the causes underlying sensory, perceptual, and cognitive declines are likely to be shared. Also, after critical periods of perceptual development have been completed, reduced sensory input in itself does not seem to exert immediate and widespread negative effects upon cognitive ability. For instance, middle-aged adults whose effective acuity of visual and auditory input was reduced to levels normally observed among older adults did not show generalized decrements in cognitive performance. Also, sensory-cognitive correlations observed in cross-sectional studies are not markedly lowered when individuals with very poor vision or hearing are excluded from the analysis.

Common cause, sensory deprivation, and cognitive permeation are not mutually exclusive explanations of the connections between sensory, perceptual, and cognitive aging. Rather, the mechanisms underlying these explanations may co-evolve and interact during the transition from early to late adulthood and old age. It also is worth noting that some functions such as selective attention remain relatively intact in old age. The various explanatory accounts converge upon the prediction that such functions are less complex, more dependent in acquired knowledge, or both. At a more detailed level of analysis, however, explanations may differ. For instance, according to the common-cause hypothesis, functions are likely to be spared when they are less dependent on the shared common influence. According to the cognitive permeation hypothesis, perceptual functions are more likely to be spared when they show less of an age-related increase in the dependence on top-down processing. Future research needs to discern the ontogenetic dynamics and relative importance of the relevant mechanisms associated with these different explanatory accounts.

Conclusion

Perception involves a multitude of interacting sensory and cognitive mechanisms. Normal aging affects all senses, with marked declines in visual and auditory processing. Multimodal mechanisms of posture control and gait also become less efficient with age. Empirical evidence suggests that sensation and cognition become increasingly intertwined with advancing age. Progress in understanding perceptual aging, with the goal of effectively attenuating its adverse consequences on everyday competence, requires an explicit focus on dynamic interactions between age changes in bottom-up sensory and top-down cognitive processes.

See also: Balance, Posture and Gait; Hearing; Intelligence; Memory; Social Cognition; Vision.

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Personality

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Glossary

Neuroticism – The (basic) tendency to react with anxiety, hostility, or obsessive-compulsive behavior in interpersonal relationships or faced with demanding situations in life.

Phenomenology – A method for describing the individual's primary experiences of events. Phenomenology often refers to the perceptual, evaluative, and meaning-giving processes within the individual.

Projective Test – A standardized psychological measurement whereby personality attributes are measured indirectly. Projective tests consist of ambiguous stimuli (persons and situations) onto which the individual projects internal motivations and dispositions.

Psychogerontology – A scientific field of inquiry focused on psychological development and aging. Psychogerontology addresses questions of cognitive aging (intelligence, learning, memory) as well as questions of personality development and mental health.

Self-Concept – Self-awareness, or the way the individual views him- or herself (in relation to others). The self-concept consists of the motivations, attitudes, and behaviors that are relevant to self-definition.

Transactional Processes – Interactive processes between the individual and his or her environment, in which human consciousness (personality) is seen as an ongoing stream and the adapting acts of the individual are in focus.

Introduction

Personality can be defined as the individual characteristics of a person in the way he or she reacts to events. The construct of personality pertains to the internal character as well as the external behavior that differentiates one person from another. Personality psychologists differ remarkably in which aspect of personality they stress. There are those who point to the inner awareness or reflectivity of an individual, called the self, as the core of personality. Others stress outer factors such as learned expectations or the repertoire of learned behaviors. And there are those who are interested in the structure of mind and the profile of personality traits, as well as those who advocate that personality can be observed only from the individual's life as a whole.

Three interrelated themes characterize the field of personality and aging. One theme is the various theoretical and research approaches to the concept of personality. Second is the analysis of whether personality changes over the years, and if so, which aspects show stability and which aspects change. A third theme is the question of how aging individuals can cope with the daily hassles and the major life events that old age brings about. These themes are reflected throughout the sections that follow.

Theoretical and Research Approaches to Personality

The metaphor personality that psychologists have created is a nebulous construct encompassing a multitude of theoretical concepts, research issues, and methods. The three major traditions in personality research – the trait model, the developmental model, and the experiential-contextual model – were created long ago but are all still alive and well. These three models differ widely in their definitions of the concept of personality as well as in their ways of measuring it.

The three traditions also differ in the balance between theory and empiricism. The developmental tradition is characterized by more theorizing, whereas the trait tradition is more empirically oriented. In the experiential-contextual tradition, some models of person-situation interaction have been formulated, and research data in support of these models are gradually emerging.

The Trait Model

The trait model has for some time now been one of the dominant personality research traditions. This model aims at uncovering the basic dimensions of descriptive adjectives of personality found in natural language. There is both a lexical and a questionnaire approach to traits, however. Personality traits are measured by tests and self-report instruments, with the dimensionality of the measures validated by factor analysis.

Personality is inferred in the trait model from the metrical representations of self-reports. It can be argued that the behavior of variables in the metric space is studied in this research tradition, rather than the behavior of persons in real life. The critics of this vigorous research tradition point to its mechanical and abstract way of measuring personality and they question the validity of the sampling of personality constructs used in the instruments. A central question here is how well the tests cover the behavior of the individual in everyday situations. The main issue, thus, is the ecological validity of the tests. Multitrait multimethod (MTMM) analyses linking together self-report measures, peer ratings, and behavioral measures have produced a rather delineated picture of the main personality constructs of the trait tradition and their validity, however.

The Developmental Model

According to the second dominant research tradition, the developmental model, either there are qualitative shifts, such as stages or phases found in the development of personality, or there is a more continuous development around certain themes throughout life. The development model, along with the trait model discussed previously, has generated the majority of empirical research findings within the field of personality.

In the developmental model, the level of development is mapped by measuring instruments (some of which are trait-oriented) or by observation of behavior in social roles or around developmental tasks. In some developmental theories, stages or periods of life are postulated representing qualitative shifts in behavior (such as the development of generativity in middle age and integrity in old age, as in Erik Erikson's theory). In these models, the stages follow each other in fixed succession, advancing from more immature to more mature levels. In other developmental theories, timetables are postulated that are closely linked to chronological age (such as the succession of stable phases and transitions in the life structures, as in Daniel Levinson's model). These theories are mostly based on Freudian reasoning, focusing on the development of the ego and the defense mechanisms the ego uses to protect itself from feelings of distress through life.

In the theories that pertain to a more continuous development, certain developmental themes considered typical for a life period (such as middle age) are investigated. Carl Jung, for instance, focuses on the midlife transition, where the balance of extraversion versus introversion shifts and where an individuation process leads to increased maturity in old age. For the general developmental model, the interesting question is how changes vary in an orderly way, regardless of the direction of change. The general developmental model can depict decline, and decrement with compensation, as well as growth in personality-linked issues.

The stage theories, such as Erikson's, are criticized because they do not seriously take situational and cultural factors into consideration but rather presuppose universal developmental stages for a human being, seemingly irrespective of context. Although the stage and phase theories were conceived long ago, they have not initiated much empirical research that would test their credibility. Daniel Levinson's model can be criticized for making general statements about development for the two genders although his original research sample consisted only of men, and for a rigid chronological time structure that does not take into account sociohistorical change.

The Experiential-Contextual Model

Lately, the experiential-contextual model, which was initiated in the 1960s and constitutes the third tradition in personality research, has grown strong again. In this model the evolving lives of persons and the

meaning people ascribe to life events are in focus. The trajectory of personality change is mapped over extended time intervals, and social and historical factors are considered as important as individual ones.

Within the existential-contextual model, the constructionist approach emphasizes the situations and contexts in which persons create their own selves and those of others. If stability or change are found in personality across the years, this research tradition looks for explanations in the sociocultural and historical context. Accordingly, another characteristic of this approach is to see old age as basically produced and shaped by social factors; there is thus a research interest in uncovering 'the social construction of aging,' for example, in Glen Elder's studies on developmental conditions during the Great Depression.

In the life story approach, another direction within this model that is also based on a life span perspective, personal accounts are studied in order to get a picture of development and aging 'from within' through the stories the self narrates at different points in time. In the life story approach, the phenomenology of the narrator is in focus, and the sociohistorical factors are seen through the interpretations of those factors given by the narrating person. The accounts of lives are collected and analyzed concerning life events, developmental tasks, life projects, turning points, life demands, traumata, life stress, and daily hassles (e.g., the studies by Susan Whitbourne on identity formation and by Dan McAdams on the making of the self, both of which were based on life stories).

Retrospective and prospective data as well as accounts of the present situation are considered useful in this research tradition. The level of analysis can vary from the study of single cases to the study of groups, and from cohorts to subcultures of aging individuals.

The experiential-contextual model seems promising in its ability to combine individual and sociohistorical (internal and external) factors and to study their interrelations in time. In this tradition the management of the self in demanding life situations can be studied, as well as the possibilities of the self proactively creating and changing life circumstances. This method has not yet, however, produced enough data to allow evaluation of its scientific significance within the field of personality.

Findings from Research on Personality and Aging

Results from Research in the Trait Tradition

Traits Costa and McCrae have in several rather extensive studies addressed the question of whether personality 'sets like plaster' at some point during the life span and then remains unchanged, or if change can be found with time. Their studies have been based on a five-factor model of personality traits: neuroticism (N), extraversion (E), openness (O), agreeableness (A), and conscientiousness (C). In some of the studies, a revised N, E, O personality inventory (NEO-PI-R, with full-length measures of the five factors) has been used. The five constructs in a rather systematic way organize hundreds of personality traits proposed by theorists using adjectives that emanate from natural language to describe personality features.

The N scale measures anxiety, hostility, depression, and other variables that refer to maladjustment and psychopathology. N is an important concept because it has been shown that neurotic elderly individuals do not cope as effectively with stressors like severe losses in old age, and that a close relationship exists between low scores for N and subjective well-being. E pertains to external activity, positive emotionality, gregariousness, and assertiveness. O includes intellectual curiosity, active fantasy, and differentiated feelings. A consists of tender-mindedness and compliance. C consists of orderliness, self-discipline, and need for achievement.

Both cross-sectional and longitudinal methods have been employed in the N, E, O, A, and C trait studies. The cross-sectional studies tend to show small declines in N, E, and O and small increases in A and C in older age groups. One of the studies was based on a substantial sample of 10 000 men and women aged 35–84. Similar results have been obtained with smaller samples in other studies. The problematic nature of cross-sectional designs makes the interpretation of these results difficult, however. It can be questioned whether we are seeing in these results the personality features of the different generations under comparison, or if we are really seeing systematic changes in personality with advancing age.

The longitudinal and cohort-sequential studies based on mean levels show another picture: no change or very modest change in personality traits across the years. A 6-year longitudinal study by Costa and McCrae did not show systematic changes in N, E, and O. In overviews of the research on general anxiety, a stability has been reported, but this pertains only to trait anxiety. For more contextual anxieties and fears it is clear that the aged show higher levels of fear, for example, fear of becoming a victim of crime or elder abuse (*see* Abuse and Neglect of Elders).

The picture of no, or little, change in personality traits by age is further strengthened by stability estimates (retest correlations) of individual differences.

The Costa and McCrae research group, as well as other research groups, have in several studies showed considerable stability effects in comparing the rank order of individuals in their personality traits over time. When the studied correlation coefficients are corrected for estimated error of measurement they reach as high as 0.90, which indicate substantial stability. In a study using the Social Introversion Scale of the Minnesota Multiphasic Personality Inventory (MMPI), a stability coefficient of 0.74 has been reported for a follow-up from middle adulthood (30 years) into late middle age.

Correlations across personality components have shown the greatest instability during the formative years, especially in late adolescence to early adulthood. Around age 30, personality presumably takes its final, fully developed form, staying roughly the same over the life span. Stability in personality traits is typical of older adult ages, according to many studies. If correlations among personality components are extended over very long time periods (i.e., over 50 years), a decline in consistency is evident, however, indicating the possibility of some change. But the decline, when it occurs, is generally modest.

In longitudinal studies of persons aged 21–84, based on Cattell's Sixteen Personality Factor Questionnaire (16 PF), Warner Schaie has shown that excitability of emotions is the only trait that increases over the years. Some of the traits in the 16 PF did show age differences in cross-sectional analyses, indicating that they were actually cohort effects.

According to Freudian reasoning, old age should be accompanied by increased rigidity of the ego. In some longitudinal studies by Schaie and his associates this assumption was not confirmed, however. Their studies showed stability both in behavioral and in attitudinal flexibility over the years.

The measuring instruments of personality concepts in the main longitudinal studies within the United States vary widely. This hampers the comparison between projects considerably. On the other hand, generalizability is much enhanced when a robustness in results and resemblances among factors measured in different studies can be found. When the constructs used in the studies are factor analyzed, they do produce factors with reasonable resemblance to Costa and McCrae's N, E, O, A, C model. These results give additional support to the principle of structural invariance in personality over the adult life-span.

Motives Other theorists within the differential psychological research approach have postulated conceptions other than trait as the fundamental unit of personality. According to the Murray tradition, motive is such a unit. Three basic motives – achievement, affiliation, and power, have been studied in depth, within a life-span perspective. Projective tests (such as the Thematic Apperception Test [TAT]) have been used for indirectly assessing motives (defined as dispositions to find a class of incentives attractive). Studies linking the N, E, O, A, and C traits of Costa and McCrae with motivational factors from other types of research have appeared, suggesting that the Murray motives can possibly be conceptualized as motivational traits.

Researchers with a motive approach have challenged the stability claim that has arisen from the N, E, O, A, C studies. Longitudinal studies using the Edwards Personality Preference Schedule (EPPS) have found increases in the achievement and dominance motives and decreases in the abasement and affiliation motives by age, possibly indicating maturational changes in adulthood. Another study has indicated that the need for achievement decreased for employed women who did not get promotion in midlife, and that the power motive was highest for men in midlife.

There are also other longitudinal data implying some personality change from adulthood to middle age. The indication is, therefore, that there are personality constructs that do show changes over time in adult life. It is a challenge to further research to identify these more change-prone aspects of personality.

Control Beliefs Julian Rotter's locus of control idea has initiated some studies that map stability and change in control beliefs over the life span. This research tradition goes back to learning theories that postulate the existence of generalized expectancies concerning behavior possibilities, based on reinforcement. Thus, the individual's feelings of outer control from the caregiving parents would be typical of the childhood years, whereas feelings of increasing inner control in young adulthood will grow out of newly gained independence. Decreased internality of control beliefs is postulated again in old age, when advancing frailty might lead to an increased need for assistance and care.

The research group led by Margy Gatz has generated most of the longitudinal data concerning this issue. In a cross-sequential study with a follow-up of 20 years there seemed to be strong evidence for continuity of internality over the adult years. The mean levels of personal control actually became more internal in all the young, middle-aged, and old-age groups followed in this study, a finding that probably reflects changing contextual factors in the culture. At the same time, the oldest women showed more outer control, most probably a cohort effect. In addition to the gender difference, the researchers point out the

great individual differences found concerning this attribute.

According to some researchers, the inconsistency in some other longitudinal research projects on this issue can be explained by the unidimensional way of defining control (as inner or outer control). Multidimensional approaches might thus be needed. The European researcher Jochen Brandstädter has shown in a cross-sequential study of developmental goals that self-perceptions of autonomous control became more pronounced in middle and late adulthood. This control concerned the domains of health and physical well-being, assertiveness, self-assurance, intellectual efficacy, self-development, mature understanding, and wisdom. Recently, researchers have started to stress the need for studying personality-linked concepts such as control, self-efficacy, or autonomy as transactional processes rather than as personality traits. Where these concepts are studied as processes, the relation between the aging individual and his or her environment will be the focus of the research.

Beliefs Concerning the Future A positive future outlook on life has favorable influences on health-related factors, and the existence of hope has favorable effects on psychological well-being. Future time perspective has been defined as the outcome of cognitive and emotional interactions in the aging person. The European gerontologist Hans Thomae has shown that the existence of a positive future time perspective is related to lifestyle, open-mindedness, emotional responsiveness, active coping, and good adjustment. Those aging individuals who did not attain an inner locus of control, as well as those whose control was lost late in life because of severe illness, exhibit more negative outlooks for the future.

These trends have been confirmed in studies of elderly married women. Women who showed a negative attitude toward the future were socially isolated and devalued by their husband and children, and this detracted not only from their feeling of being needed, but also from their satisfaction with life in general.

A pattern of beliefs in the possibility of changing one's life has also been investigated. The beliefs pertain to the possibility of improving conditions in old age. It has been shown that those with higher income, better subjective health status, and stronger feelings of being needed by others more often show these kinds of beliefs. The stronger the self-perceptions of autonomous control over individual developmental goals are, the more optimistic is the individual's outlook on aging. With a decreasing sense of personal control of life circumstances in old age, symptoms of resignation and depression may emerge (*see* Depression).

Results from Research in the Developmental Research Tradition

General Developmental Conceptualizations

Research on the themes of middle age has produced optimistic as well as pessimistic descriptions. Middle age has been depicted both as a period of increasing maturity and individuation and as a crisis-prone period of life characterized by turbulence and transitions.

According to Jung, a young person will be more extraverted than an old person. After middle age there is a shift in the introversion–extraversion balance. An old person will show increased introversion, and his or her reflectivity on the life he or she has lived will help the individual to develop wisdom. Jung stressed also the process of individuation in midlife, in which the individual becomes increasingly aware of the masculine and feminine features that both men and women show in their personalities. Another aspect of the individuation process is the recognition of both good (moral) and bad (immoral) features of one's personality.

Bernice Neugarten stresses the increased capability of steering one's own life and mastering one's social environment instead of just adapting to it, as in earlier periods of life. The middle-aged cohort has been described as at the top of its capacities and powers. It has also been described as dominating other age cohorts. Studies show that middle-aged men, compared to younger and older men, have the most positive self-concept. Men seem to value career roles highly in this period. At the same time they evaluate their marriages as more satisfying than women do. Women in middle age have been described as possessing a larger and more flexible role repertoire than men. A defense mechanism of rejecting feelings of possible problems and misery seems to add to the feelings of life satisfaction among middle-aged men. The early middle-age period in particular has been seen as a period of active mastery of life themes.

According to Roger Gold, middle age is also a period of reevaluation of earlier assumptions and expectations concerning self and significant others. There are pushes for a reevaluation linked to an arrested career development, the empty-nest issue, and changes in roles. Also, insight on a limited time for life planning as well as insight on the restriction of one's own capacities push for change. Only through a series of transformations will growth toward an increased inner directedness be possible.

Middle age is also a period characterized by an increase in divorce rates, health problems, and psychiatric disorders. Another sign of being middle-aged is that friends and colleagues fall ill and die, perhaps activating thoughts of one's own mortality. The efforts to master these major life events often take the form of personal crises. According to studies, the feelings of loss, reevaluation, and depression are widespread at the peak of a crisis. But when the peak is over, these feelings are gradually replaced by feelings of accepting the realities of life and feelings of the necessity of reorientation.

Large individual differences exist concerning the smoothness versus abruptness of development in middle age. The middle-age transition may pass almost unnoticed by some, whereas individuals who resist change or cannot accept losses or occasional failures seem to be the most crisis prone, according to Levinson.

Earlier it was believed that old age was characterized by increased rigidity and dogmatism. Longitudinal studies show that this usually is not the case. An increased cautiousness (i.e., a lesser willingness to take risks) is still presumed for the aged, however. Studies have suggested that older individuals comply more to social norms and are less aggressive than younger age groups. Neugarten labels the change from active to passive mastery that is typical for the oldest of the old as interiority.

Increased interiority (or even magical mastery) is a male-specific aging phenomenon, however, as David Gutmann found in his comparative anthropological studies. For women, the developmental trend would be the opposite, from passive mastery to an even aggressive mastery. This developmental shift has been seen as a liberation from sex role stereotypes in late old age (*see* Gender Roles).

Levinson's Model of Developmental Periods Levinson's model describes the developmental periods of early adulthood to late adulthood (ages 17–65). The central concept in this model is life structure. The life structure consists of three levels: the sociocultural level (social contexts of class, ethnicity, religion, and political system); the personal level (the self and realization or inhibition of self themes); and the behavioral level (individuals' participation in the world, in significant roles—occupational, familial, and societal). Levinson's own study of 40 men as well as a few other studies seems to affirm his theoretical formulations.

The life structure, according to Levinson, evolves through a relatively orderly sequence during the adult years and this sequence is bound to chronological age (this assumption has been much debated). The developmental task of a life period is crucial for the evolution of the period. (In what follows only the midlife transition will be presented. The other period with significance for aging is the late adult transition, but this period has not been described in detail in Levinson's presentations.)

The developmental tasks of the midlife transition (ages 40–45) are connected with a review and termination of early adulthood, with the initiation of middle adulthood, and with dealing with four polarities in life. There is a need for reevaluation of the relation to the spouse, to the job and one's superiors, to one's mentor, and to one's own values and strivings. Levinson reports that 80% of the men in his study experienced a repeated questioning of and a struggle with these life themes. The need for change will be felt in some areas, and experimentation with new solutions and modification of the life structure will thus start.

The four polarities whose resolutions are considered the principal tasks of midlife individuation are young–old, destruction–creation, masculine–feminine, and attachment–separateness. The most important one is the young–old polarity, which is repeatedly raised throughout life. The middle-aged period of life is experienced as 'in-between,' and the developmental task is to restructure the polarities. Old represents maturity, good judgment, self-knowledge, and getting a perspective on life; young is a symbol for play, initiation, openness, energy, and potential.

In Levinson's theory of developmental periods the concept of life structure is centered on the boundary between self and world. The theory gives equal weight to the self and the world as aspects of life lived. Erikson's theory, which is presented below, is likewise concerned with how the self is engaged with the world, but the focus in this theory is on developmental change within the person.

Erikson's Epigenetic Stage Theory The stage theory of Erikson is the only developmental theory that covers the complete life cycle, but only the last two stages (out of a total of eight) are considered here. The first versions of the theory were created as early as 1950 but they have been elaborated on many times. The most recent presentation is from 1986 and specifically concerns old age.

Three organizational principles constitute the basis for development and change: the biological, psychological, and sociocultural processes. The concept of epigenesis is used for linking the somatic development to the psychological (psychosexual) and social. The concept of ritualization signifies predicted repetitious behavior typical of a certain stage of life. The

development of new life stages arises out of the demands of the biological, psychological, and social areas during critical time periods in life.

The critical time periods in life that induce development of a person's identity are conceived as crises in Erikson's theory. The crises can be solved by finding a balance between two opposite developmental trends. A sign of a successful completion of a developmental crisis is the occurrence of new, age-typical rationalizations.

In middle age, the crises are focused on the polarity of generativity versus self-absorption, and the adaptive strength that can grow out of this crisis is care. Generativity presupposes reproduction, production, and creativity. An adult person cares for children, work-related products, and ideas. By this behavior the adult takes responsibility for the major concerns in his or her life at that time; that is, the adult takes responsibility for self and for the younger generation. The age-typical patterns of behavior, the rationalizations, include the parental and the educational roles, as well as productive and nurturant behavior (*see* Creativity).

In old age the dominant crisis evolves around the opposites integrity versus despair, and the final identity strength that may develop is called wisdom. The last crises of the life cycle accompany the visceral and muscular decrement in the somatic area, the diffusion of the border between past and present and other memory changes in the psychological area, and lost responsibilities in the social area. The major ritualization that grows out of a positive solution of the crisis is a philosophical stance toward one's own life, toward humankind, and toward death.

Wisdom is seen in the development of closeness to persons of earlier times and other cultures, representing other ways of life. But the feeling of integrity is also tied to one's own self with its positive and negative features, and to the life lived with its bright and dark periods. When an acceptance of the self and the life lived is possible, the individual is also ready, without fear, to accept death as the final event of life. The negative developmental path of this stage leads into despair. In this case, the aging individual is unable to accept and finalize his or her life, but rather feels disgust and repulsion toward other human beings, toward life, toward aging, and toward his or her own self.

The generativity typical of the preceding stage may take on an enlarged function in old age and may develop into engagement, if the solution of the crisis is positive. The increasing life expectancy of modern times presupposes new rationalizations based on vital involvement in old age, something not seen before.

Empirical studies of those parts of the theory pertaining to middle age and old age are rather scarce. A test (Erikson Psychosocial Inventory Scale [EPSI]) has been developed, however, to measure resilience to the life crises depicted in the theory. Research based on this test shows that those who have succeeded in solving earlier crises also tend to solve later crises in a positive way. Qualitative studies, by McAdams and other, give delineated accounts of some of the generativity and integrity themes told by the middle-aged and aging self.

Erikson's theory shows rather visible normative underpinnings, based as it is on American norms of development from the period of the 1950s through the 1980s. Thus, it remains to be seen how well the stages cover the development of both men and women today as well as persons from different cultures.

Synthesized Developmental Models Two humanistic, existential models of positive psychological functioning in old age have been proposed: Carol Ryff's successful aging and well-being model and Lars Tornstam's model on gero-transcendence. Both models draw heavily on earlier theorizing in the field (by Gordon Allport, Charlotte Buhler, Carl Jung, Erik Erikson, Bernice Neugarten, Carl Rogers, Abraham Maslow, and many more). The models are creative reconstructions, but seem promising in their own right.

1. Successful aging and well-being: Ryff has criticized research on successful aging for only collecting research data without drawing up models or theories for explaining them. Many researchers routinely use ready-made instruments in research without questioning how well they cover the central constructs in well-being. Some of these measuring instruments are biased against finding evidence of change by including only basic tendencies of personality and by discarding from the scales items sensitive to change. The earlier research on well-being is said to be too focused on illness rather than 'wellness' in old age, and on finding problems rather than resources.

In an effort to integrate mental health, clinical, and life span developmental theories, Ryff proposed a model for multiple positive psychological functioning based on the following dimensions:

- Self-acceptance: A high-scoring individual on self-acceptance shows a positive attitude toward the self, acknowledges and accepts multiple aspects of self (including both good and bad aspects), and evaluates his or her past life positively.
- Positive relations with others: The person has trusting, satisfying, and warm relations with others and cares for them; shows feelings of

empathy, affection, and intimacy; and gives and takes in human relationships.
- Autonomy: The person shows self-determination and independence and is capable of resisting social pressure in ways of thinking and acting. The person regulates behavior from within and evaluates self by personal standards.
- Environmental mastery: The person is competent in managing the environment and has an inner sense of mastery. The person can control a complex array of external activities, makes use of surrounding opportunities, and can choose or create contexts corresponding to personal needs and values.
- Purpose in life: The person has goals in life and a sense of directedness; experiences meaning in past and present life; holds beliefs that give purpose; and has aims and objectives for living.
- Personal growth: The person has a sense of continuous development with a growing and expanding self and increased self-knowledge over time; is open to new experiences; and has a feeling of realizing his or her own potential.

In the preceding presentation, only the positive criteria for well-being were presented. In the self-report scale that Ryff has constructed, characteristics of low scorers on these dimensions can also be found. The model does give a positive outlook on aging, but seems to describe late middle age or early old age better than late old age.

2. Gero-transcendence: A theory suitable for describing the last part of the life span is Tornstam's theory of gero-transcendence. The theory is a reformulation of the disengagement idea, advocating the quest for reaching a metaperspective on life for the oldest of the old. The theory is still tentative, and research to confirm the claims made by this theory has only recently started.

The shift in metaperspective toward gero-transcendence includes the following:

- An increasing feeling of cosmic union with the spirit of the universe.
- A redefinition of the perception of time, space, and objects.
- A redefinition of the perception of life and death and a decrease in the fear of death.
- An increased feeling of affinity with past and coming generations.
- A decrease in interest in superfluous social interaction.
- A decrease in interest in material things.
- A decrease in self-centeredness.
- An increase in the time spent in meditation.

Some evidence for these ideas can be found in the work of Robert Peck who studied the crises faced by aging businessmen. The crises were centered around ego differentiation versus job preoccupation, body transcendence versus job preoccupation, body transcendence versus body preoccupation, and ego transcendence versus ego preoccupation. In an initial study Tornstam found some evidence for the differentiation between gero-transcendence and depression and the differentiation between gero-transcendence and unsuccessful coping. The question of whether gero-transcendence presupposes a religious revival is left unanswered, however, and the theory can be criticized for its metaphysical conceptualizations.

Results from Research in the Experimental-Contextual Tradition

Personality Types, Developmental Trajectories, and Ways of Life In a classic study of adjustment of elderly men to retirement, conducted in the early 1960s by Susanne Reichard, Florine Livson, and Paul Petersen, extensive measurements and self-reports were used in obtaining the data. The researchers found five different personality types that differed in their adjustment. The mature men accepted their own selves and had positive attitudes toward aging. The rocking chair type quietly adapted to aging, enjoying their new freedom from responsibilities. The armored men, however, were not ready for retirement yet; they used overactivity as a defense. The angry men were clearly not well adjusted to retirement; they showed bitterness and blamed others for their predicament. The self-haters turned their aggressiveness inward and were disappointed and depressed.

In another now-classic study, Neugarten and her collaborators, using a multidimensional approach that included an index of life satisfaction, found four types. The integrated and the armored showed high life satisfaction, the unintegrated showed low life satisfaction, and part of the passive-dependent were satisfied and part dissatisfied with their life in old age.

These two studies used many of the traditional personality tests of the trait tradition, but also used some more open measures, such as interviews that are typical of the experiential-contextual tradition. The researchers' efforts to describe personality as a strategy of adaptation or an integrated whole (or type) are features of the experiential-contextual tradition.

It has been suggested that a way of measuring core identity changes would be to focus on the ideas and perceptions the individual has about his or her

life-span development. According to Whitbourne, it is fruitful to focus on two components, the scenario and the life story. The scenario consists of a person's expectations on how his or her life will unfold. The life story will reveal the course of identity formation, and individual values and motives, as well as normative developmental expectations in society for the cohort to which an individual belongs.

Elder has shown that only by describing developmental paths is it possible to reach an ecologically relevant perspective on individual development. The paths, or trajectories, should be examined in the context of time, locality, and social group. Elder, who studied developmental trajectories that took place during the Great Depression, points out that many of the central choices in life, such as career, can be understood only when analyzed along with the individual's personality and social background and the time during which the choices were made.

Ravenna Helson studied lives through time by focusing on normative change (change related to personality patterns and to role sequences). Helson studied a cohort of women attending college in the late 1950s. She found that 'the feminine social clock' (the developmental schedule for this cohort of women) produced self-controlled, tolerant, and responsible women, most of whom were mothers as young adults. But approaching middle age, when those women who followed the 'masculine occupational clock' had gained in independence and dominance, those who followed the feminine social clock had become increasingly overcontrolled. Thus the effect of the homemaker role was to make these women subordinate their own needs to the needs of others. These data give a more delineated pattern of when and why change occurs and the form it takes in different periods of the life-span.

In a recent Finnish study Jan-Erik Ruth and Peter Öberg studied individuals' ways of life and adaptation to old age by using life stories and thematic interviews. Six ways of life were found: the bitter life, life as a trapping pit, life as a hurdle race, the devoted, silenced life, life as a job career, and the sweet life. In these ways of life, earlier life events such as sociohistorical background, marriage, and other human relationships were handled in quite different ways. The sense of locus of control as well as the self-image varied in all of the ways of life. The life lived, clearly, had a substantial impact on the emotional tone of old age.

In the two most negative ways of life, the bitter life and life as a trapping pit, severe losses (such as health problems) and problems in human relationships and career had a negative impact on the respondents' lives and resulted in a dysfunctional old age. There were two gender-specific ways of life; the devoted, silenced life that consisted of caretaking and adherence to the needs of others (typical of daughters at home), and life as a job career where the life story was like a curriculum vitae, with little room for family values (typical of well-educated men). These two ways of life had led up to a satisfactory life or good life in old age. In the sweet life resources like intimate relations with parents, spouse, and children as well as a good education and economy contributed to a healthy lifestyle that resulted in a happy old age.

Coping The coping studies can be classified according to different conceptual frameworks. In some studies personality measures from the trait tradition are used and in some a developmental vantage point is taken. Most coping studies, however, clearly belong in a phenomenological framework, where the perception of stress and the experience of mastering a stressful situation are central. Thus, the results are considered as emanating from an experiential-contextual tradition.

In the work by Lazarus, one of the founders of research on coping, coping consists of the constantly changing cognitive and behavioral efforts to manage specific external or internal demands that the person appraises as taxing or that exceed the resources of the person. The cognitive processes in coping pertain to primary and secondary appraisal. Primary appraisal is the person's assessment of a life situation as stressful or benign and secondary appraisal is the person's perceived ways of mastering the situation.

The ways of coping have been divided into problem-focused or emotion-focused (palliative) coping; active passive coping; and approach-avoidance coping. Research data show that the more active coping strategies lead to a successful mastering of the threat in most situations, resulting in increased life satisfaction. The more passive coping strategies such as minimization of the threat, resignation, or avoidance are considered less successful.

In earlier gerontological studies, old age was depicted as rather stressful, and as a period of multiple losses. The loss of roles, income, health, and even friends and spouse were said to lead to increased distress and to a state of learned helplessness because of an increased inability to master these cumulative losses.

The results from several recent longitudinal studies of the effect of major life events in old age has altered this picture, however. In a US follow-up study of persons aged 40–70, the effects of the empty nest, retirement, retirement of the spouse, medical problems, and widowhood were examined. None of these transition

events from middle age to old age was experienced as overriding the individual's capacity to cope. According to recent data, old age is generally not an unhappy period of life or a period of low morale (*see* Retirement; Widowhood and Widowerhood).

Persons aged 60–70 were followed over a 10-year period in the Bonn Longitudinal Study. It was found that the ways of adaptation differed for persons and situations, but a pattern of constancy, rather than decrement, nevertheless constituted the major finding of the study. In a study in Jerusalem, which spanned about 20 years, this trend was confirmed. No changes in coping patterns (from active to passive) were found across the years. According to this study, coping styles were related to personality dispositions, and a variety of styles were found, from active integrative coping and failing overcoping to dependent passive coping and self-negated undercoping.

The most taxing life events in old age are, according to research findings the death of a close person, one's own illness, the illness of a close person, and giving up activities because of medical problems. But research data also show that only about half of these events occur for the first time in old age. Medical problems, for instance, usually arise in middle age. Small problems and daily hassles may constitute another source of distress in old age, however. Research shows that the coping mechanisms used by the aged are more event specific and more differentiated than was assumed earlier. Seeking social support is, for example, often used in coping with the death of a close person, but seldom in coping with involuntary relocation and giving up activities.

All adults, however, including the aged, have many resources, external and internal, to draw upon in distressing situations. External resources such as high education and high socioeconomic status usually result in coping based on logical choice and flexibility rather than on irrational and rigid solutions. Older individuals with support from the social network, such as family support, are also less likely to use the avoidance coping that is associated with lower levels of well-being (*see* Social Networks, Support, and Integration).

Some studies have suggested that accepting the situation as such, seeking emotional support based on intimacy and friendship ties, and seeking help from religion are used more by women than by men. Men use more information seeking and rely more on instrumental support and camaraderie. These differences between the genders may be cohort specific, and dependent on time-bound and culturally determined behavior expectations.

Internal resources useful in coping are tied to experience or maturation, personality dispositions, and motivation. It has been shown that younger copers rely on denial and projection as a defense mechanism in taxing situations, whereas older copers are more likely to use sublimation, suppression, and humor. An easy-going disposition and optimism are favorable personality dispositions in coping, whereas neuroticism negatively affects perceptions of stress and coping possibilities. Self-efficacious individuals and those with a disposition of commitment, control, and challenge (called hardiness) are more active and successful copers.

The above-mentioned active, and even competitive, ways of coping may be best suited for middle-aged persons and the newly retired, however. Old persons may be better served by accommodating to negative life events, like severe illness, and reassessing the events in a more positive way, or by lowering their own aspiration level. For the frail elderly, the behaviorally oriented coping mechanism may be replaced by more psychological ones, such as relying more on acceptance coping in situations in which they genuinely have little control.

Management of the Self A change can be seen in gerontological research in approaches toward the construct of the self. A more active, creative, and competent self emanates from recent findings. In studies of coping presented previously, there is an increased consideration of resources available for the aging individual. The self is thus no longer seen only as a passive, reactive agent battling life stress induced from outside. In the process-oriented, narrative research tradition there is a possibility of change, in reconsideration and revision of previous history and future plans.

The self-concept is made up of the attitudes, goals, and behavior relevant to self-definition and the meaning of life. This is an enlargement of the former perspective of studying only the actual self, ideal self, and self-esteem, as proposed by Rogers. Now a variety of actual and possible future selves are the focus of research: the good, the bad, the hoped for, the not-me, the ought-to selves (*see* Self Esteem).

Persons of all ages have a tendency to perceive themselves as loving, competent, and good. If they cannot perform a role well, they have a tendency to devalue its importance and put emphasis on other roles that add to their feelings of competency and self-esteem. Another principle of self-concept management is downward social comparison (i.e., a comparison of the self with those even worse off). Other possibilities are attributing failures to external, unyielding causes, and deemphasizing the importance of unattainable goals and emphasizing more

attainable ones. Research data show that in old age the discrepancy between the actual self and the ideal self decreases. Old individuals also stress the need to accept change and lower their expectations in life in order to achieve continued well-being.

Earlier studies showed that elderly women report more health problems and report feeling more lonely than men. Many old men are still living in intact marriages, but even those men who live alone do not report feeling as lonely. Recent data indicate, on the other hand, that a sense of aloneness resulting from multiple bereavements might be compensated for by a feeling of special status as long-term survivors, for both women and men. Data including many age groups also show that deep feelings of loneliness may occur in many phases of the life-span (such as in the teens), rather than only in old age.

The resilience of the self in old age is based on interpretive processes such as reappraisals and social comparisons, but when the self encounters challenges of frailty, a difficulty in identifying possible future selves may occur. It is also more difficult to use selective interaction and feedback from others to formulate new selves. The social interaction is then used for reconfirming the old self and for maintaining hope. Institutionalized elderly often strive to keep their life story intact, and defend against including problems connected to institutionalization in it.

Thomae's Cognitive Theory of Adjustment to Aging Gerontology is data rich but theory poor, according to James Birren. In recognition of that criticism this review ends with some recent theoretical formulations, the first of which was created by Thomae.

Thomae's cognitive theory of aging, which was formulated in 1970, falls under the experiential-contextual framework. In the Bonn Longitudinal Study of Aging (BOLSA), many aspects of the therory have been empirically verified over the years.

In this theory, fixed personality traits are of no interest, but personality is viewed as a process, with the coginitive representations of life situations in focus. According to Thomae, both cognitive maintenance and cognitive restructuring are possible in the individual's adjustment to different situations in life.

Central concepts in this theory are the perceived situation as well as the perceived self. The perception of a life situation, rather than its objective characteristics, is related to behavioral change. The situation, the resources of the individual, and the possibilities for change are perceived according to the needs of the individual at the moment.

Three postulates are basic to this theory:

1. Perception of change rather than objective change is related to behavioral change. This also concerns perception of present, past, and future life and its impact on behavior.
2. Changes and situations are perceived and stored in the memory based on the dominant concerns of the individual. This acknowledges both emotional and motivational factors in the cognitive representations.
3. Adjustment is dependent on achieving a balance between the cognitive and motivational structures or systems of the individual. This postulate focuses on the cognition–motivation interaction in adjustment to problems in old age.

The interrelation between the aging person and his or her enviornment has been stressed in the research based on this theory. Complex competence models including both situation-specific and person-specific areas of social competence have been advanced. In a concept such as social competence both the individual's capacity to meet social (and biological) demands and society's capacity to meet an aging individual's needs have to be considered concomitantly.

Situation–individual interaction patterns have been found in studies on stress and coping in old age, where the specific demands of the situation are met with a specific way of adaptation. The distressing situation can be dealt with cognitively, for example, by accepting what has happened, attaining a distance, or focusing on the bright side of the situation. But adaptation to the situation can also be behavioral, such as adapting to the needs of others or actively establishing new social contact that can provide help. In Thomae's BOLSA studies, the individual has been depicted as an active decision maker, not as just passively adjusting to life stress.

Selectivity Theories Three models based on the selectivity principle have been created within psychogerontology; Laura Carstensen's socioemotional selectivity theory, the selective optimization with compensation model of Paul and Margret Baltes, and Powell Lawton's press-competence model. The conceptualizations differ considerably in their scope, however, and are presented below by moving from the most limited to the most general case.

1. Socioemotional selectivity theory: In Carstensen's socioemotional selectivity theory, the decline with age in initiating new social contacts is explained. It is argued that less social interaction in old age is deliberately chosen by the individual and is not

a sign of social disengagement. According to this theory, social interaction has three basic features: information acquisition; development and the maintenance of identity; and regulation of emotion.

It is argued that in the earlier phases of life increasing social contacts will give access to needed information about life and provide a multitude of developmental models and opportunities. As people age, the need for different kinds of information is reduced and becomes increasingly specialized. Sources other than social contacts (e.g., books and data files) can provide information.

During the life course individuals use a considerable time negotiating their identities with significant others. When the self-conceptions are getting more fixed later in life, only close social partners of long duration can have this self-confirmatory function. Many social partners will not share enough history to verify identity. Close family members and longtime friends, however, provide this function. Thus, these social contacts are selectively chosen and preferred over the overcrowding of social partners in milieus like retirement homes.

The cultivation of a social environment to maximize potential for the experience of positive emotions and minimize negative ones is a deliberate way of regulating affect. In old age, contrary to earlier expectations, no emotional flattening occurs. According to research findings, old age seems to bring an improved understanding of emotional contexts and meanings.

2. The selective optimization with compensation model: Paul and Margaret Baltes's principles for selective optimization with compensation constitutes a general model for successful aging. The model has grown out of the ideas of plasticity and self-resiliency and out of recognition of increasing heterogeneity among individuals in old age.

Persons may be engaged in a process of selective optimization with compensation throughout life, but this process takes on a specific significance in old age, because of lessened biological, mental, and social reserves. By selectively specializing in those areas the individual values highly, the limitations brought on by age can be overcome. This theory resembles Carstensen's socioemotional selection theory, but depicts the psychological adaptation process in aging more generally.

The model is based on three principles:

- The selection principle is seen in a restriction of the individual's world to fewer domains of high priority. The selection process presupposes an adjustment of an aging individual's expectation of satisfaction and control.
- The optimization principle makes it possible for aging individuals to enrich and augment their general reserves and maximize their effectiveness within their chosen life course.
- The compensation principle becomes operative when specific behavioral capacities are reduced or lost and the individual is using a great deal of time or effort to maintain a high level of performance.

A good example of these three principles is provided by Baltes and Baltes, who describe how the aging pianist Artur Rubinstein conquered the weakness in his piano playing in the following way: first, he reduced his repertoire by selective choice of those piano pieces he knew best. Second, he optimized his performance by practicing these pieces more often than when he was younger. Third, he compensated for his increasing slowness by retarding his playing prior to fast passages, which gave an impression of movement in the appropriate passages.

3. The press-competence model: The two previous models based on the principle of selection resemble a third, even more general model: the press-competence model created by Lawton. This model depicts the interaction of persons and environments in producing adaptive or maladaptive aging. The older person is said to construct appropriate environments by selection. An extraverted individual functions best in a stimulus-rich and even stressful environment, whereas an introverted individual functions best in a stimulus-poor and less stressful environment.

Motivation differs by temperament, and neural activation may push an individual toward the external environment (extraversion) or toward internal processes (introversion). In the ideal case, environments match individual competencies. Through the choice or construction of a more suitable environment, the restrictions of old age can, at least partly, be overcome and an optimal fit between person and environment can be achieved.

Conclusions

This article points to the importance of how personality constructs are conceived and measured in psychogerontology. If personality is defined as basic tendencies or traits, as in the N, E, O, C, A five-factor model of personality, the results in longitudinal studies will show stability or only minor change over the years. In the trait tradition, the self is not considered as an active and purposeful agent in a person's life but as an epiphenomenon that passively mirrors the basic tendencies (traits) and the dynamic processes between them and adaptation to life situations.

According to the developmental tradition, personality is defined as motives, commitments, and roles, which represent units more transient than traits; hence, there is possibility for change across the years. In the developmental tradition, the research focus is on the development of the self and its defense mechanisms. The developmental stages or periods depicted in some developmental theories presuppose change in a regular or time-bound order for a positive solution of developmental crises met by the individual throughout life.

In the experiential-contextual tradition, adapting is conceived as a subjective biography, or as mastering based on perception, evaluation, and meaning-giving in the situations encountered by the proactive self; change in personality will not only be possible, but probable throughout the life span. The models and theories within this tradition conceive personality as transactional processes characterized by continuous calibrations in the person–situation interaction.

See also: Creativity; Depression; Gender Roles; Retirement; Self Esteem; Social Networks, Support, and Integration; Widowhood and Widowerhood.

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Pharmacology

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Glossary

Enzyme – A biochemical that catalyzes reactions between other biochemicals without itself being consumed.

Ester Linkage – The chemical bond formed in the reaction between organic acids and alcohols uniting them into organic salts called esters.

Glucuronic Acid – A naturally occurring organic acid derivative of glucose used in bodily processes to detoxify drugs and render them excretable.

Hydrolysis – An enzymatic cleavage of an esteric drug. Hydrolysis breaks the ester linkage and returns the compound to its acidic and alcohol constituents.

Introduction

Pharmacology is a discipline concerned with the study of therapeutic medications, their effects on the body, and, conversely, the effects of the body on the medication itself. As a science, it provides the theoretical substrate for the rational prescription of therapeutic agents and is an important element of the physician's training and knowledge base. A cognate discipline, toxicology, the study of the toxic effects of a multiplicity of chemicals, including therapeutic compounds, is sometimes included in pharmacology.

Pharmacology's goals are to pursue an understanding of the mechanisms by which drugs exert their therapeutic effects and adverse consequences and to provide theories for development of safer and more effective agents. The pioneer medicinal chemist Dr. Paul Ehrlich called the ideal drug the silver bullet: it would act rapidly, act only on the targeted disease, organ, or system for which it is administered, and be completely curative. Ehrlich's aphorism remains the unwritten standard for pharmacologists who work today as his successors. Sadly, despite many astounding advances in the discovery and development of therapeutic chemicals, there is no medicinal agent that approaches this ideal. Medications are usually given to achieve one effect on a target disease, but all cause additional effects beyond the one for which they are prescribed. These effects are unwanted, sometimes unanticipated, and can be disabling and even fatal. Despite a host of undesirable non-therapeutic effects, for the majority of patients to whom they are prescribed, drugs continue to help, and even cure. But they remain problematic for many, especially elderly patients and the physicians who prescribe for them.

For a drug to be effective, it must appear at its intended site of action in adequate amounts. The degree and rapidity with which the body is able to absorb, transport, metabolize, and excrete an administered medication may determine that medication's efficacy, therapeutic effects, unwanted side effects, and ultimately the success or failure of the treatment. The ability of the body to perform these functions is, of course, determined by the functional state of the organ systems subserving them, organ systems that may be altered by age and/or disease. The body's ability to handle a drug may be adversely affected by both age and illness, but the relative strength of these two variables is difficult to specify. To help overcome this quandary, an expanding number of studies conducted in groups of healthy older volunteers are contributing important data by which to formulate a general pharmacology of the older patient. Moreover, pre-marketing evaluation of therapeutic compounds, traditionally carried out in relatively small populations of selected younger adults, increasingly includes studies performed on geriatric populations. While the elderly are by no means a homogeneous group, such studies provide the manufacturer, regulatory agencies, and ultimately the practitioner with data reflecting the distinctive requirements of the older patient. With data from tests of such parameters as effective dose, absorption, metabolism, distribution, excretion, onset of action, and side effect profile, predictions can be made of the drug's actions as affected by the altered physiology and special circumstances found in many elderly patients. Health-care professionals have long known, through observation and anecdote, that because of age-related changes in organ physiology and multiple system decompensation, the elderly are likely to show increased sensitivity to medications and are at risk for adverse reactions. The growing body of theoretical and experimental pharmacology from this special population largely substantiates these empirical notions and provides a database to better inform and guide the health-care professionals who care for the elderly patient.

The increasing size and special pharmacological requirements of the geriatric subpopulation energize the thrust for developing a pharmacology for this special group. Not only is the group increasing in absolute size, but the elderly also characteristically visit physicians, are admitted to hospitals, and are prescribed medications at a rate greater than other subpopulation groups. They are more likely to be administered several medications at once (polypharmacy) and for longer periods of time. All of these factors collectively contribute to one of the more vexing pharmacological problems in the elderly, that of non-compliance. More than one-half of elderly outpatients reportedly do not take their medications as prescribed, with underutilization being the predominant deviation. Causes for non-compliance include forgetfulness, misunderstanding of verbal directions, inability to purchase the medication, trouble with side effects, difficulty in swallowing larger capsules and tablets, and, for the frail and arthritic, inability to open some medication containers. For many elderly patients, the sheer numbers of concomitant prescription medications is the problem; it is not unusual to observe an elderly patient arriving at an appointment, carrying his or her medications in paper bags. Many elderly are under the concomitant care of more than one physician and purchase medications from more than one pharmacy; they often accumulate as many as 10 to 15 simultaneous medicaments for themselves. The majority of drugs for elderly outpatients are taken orally, two to four times per day. Such numbers make the patient (or caregiver) responsible for administration of 20 to 30, or more, dosages each day. Under these circumstances, perfect compliance cannot reasonably be expected. Of course, not every alteration in regimens of medication self-administration is necessarily detrimental or contraindicated: in some instances, changes are made because of side effects and toxicity, wherein lowering the dose is the sensible course to follow. Conversely, the dose of a medication may be increased above the prescribed level when the patient correctly perceives an absent or reduced therapeusis.

The patient's adherence to a medication regimen is crucial to the prescribing physician's ability to correctly assess the effect of the medication; any alteration in the regimen should be reported by the patient or caregiver. Such cooperation may be vital to a successful treatment outcome. Unfortunately, the actual effect of incomplete compliance and the magnitude of any deleteriousness to the health of the elderly have not received the research attention they obviously deserve.

This article is intended to outline some basic principles of the discipline of pharmacology and to comment on how these principles apply in the special circumstances of the elderly patient. Emphasis will be given to the important determinants of drug absorption, distribution, metabolism, and excretion. Particular attention will be given to pharmacokinetics, the correlation between a drug's effect and its level in the blood, and to pharmacodynamics, the study of a drug's effects and the bodily mechanisms through which it exerts the effects.

Pharmacokinetics

Pharmacokinetics is concerned with the association between the pharmacological effects of a drug and its concentration in the blood. By studying the drug's blood level, a more accurate estimation can be made of the amount of the drug actually in the body than can be obtained from measuring the oral dose, even if given on a dose per body weight basis. The drug circulating in the blood is one step closer to the target, and its concentration more closely correlates with concentration at the target tissue. The drug's half-life also allows predictions about the time required after multiple doses to reach a steady state level. When considered necessary, information for hepatic and renal clearance and volume of distribution for a drug can be obtained by specialized pharmacological procedures and tests, which may be of utility in severely compromised patients undergoing intensive and prolonged therapy.

Drug Absorption

The most common route for medication administration for all patients is by mouth, with subsequent absorption from the gastrointestinal tract, through the wall of the stomach and/or intestine. In special situations drugs may also be administered by injection intramuscularly or subcutaneously; by intravenous infusion; intrathecally, intraperitoneally, sublingually, rectal suppository, transdermally, inhalation (gases and aerosols through pulmonary membranes), or instillation into the conjunctival sac of the eye; or topically on mucous membranes and the skin. This discussion concentrates on the fate and actions of drugs entering the body through the gastrointestinal tract, with exceptions noted. Absorption from the gastrointestinal tract is mainly by passive diffusion, but certain drugs may be actively transported by cells in the lining of the tract that ordinarily absorb molecules from digested food.

Almost all medications are either weak acids or bases, which may exist in solution in both ionized and un-ionized forms. They can be further divided into two categories on the basis of their solubility. The lipid-soluble (also called non-polar or lipophilic) drugs are not soluble in water and thus, unless specially prepared, cannot be given via routes (e.g., intravenous) that may require an aqueous transport medium for administration. They pass easily through most biological membranes, however, and are thus readily absorbed through the gastrointestinal tract. The more un-ionized the drug, the more lipid soluble (non-polar) it will be. The water-soluble drugs, also called polar or hydrophilic, tend to dissociate into negatively and positively charged ions when dissolved in water. These characteristics may influence how well a drug is absorbed and distributed in the body and, ultimately, how much reaches the target site.

The acid (low pH) environment of the stomach may affect absorption of drugs in several ways. Weak acids will remain mostly in an un-ionized (more lipid-soluble) form and be more readily absorbed through the stomach wall membrane. A weak base, on the other hand, often becomes more highly dissociated into its ionized (more polar and less lipid-soluble) form and hence is not easily absorbed through the gastric wall. Once the drug reaches the basic (higher pH) environment of the small intestine, converse conditions may prevail: weakly acidic drugs often show an increased ionization and become less absorbable, while the weakly basic drugs are frequently less ionized and more absorbable.

While some drug absorption takes place in the stomach, the thickness of its wall, its mucosal lining, small surface area, and strong electrophysiological resistance render it a less-than-optimal organ for absorption of most drugs. It is important, therefore, that the drug pass quickly from the stomach into the small intestine: the more rapid the stomach-emptying time, the more rapid the absorption of the drug. The inner surface area of the intestine is much greater and its wall is thinner, with a lining that promotes passive absorption. The epithelium that lines the intestinal wall also contains cells with mechanisms that actively transport certain drugs out of the intestinal lumen. In any case, the rate of absorption from the

intestine is much more rapid than that from the stomach, even for a drug remaining largely un-ionized in the stomach. Some drugs may be inactivated or destroyed by the stomach's highly acidic juices; the manufacturer may give a particularly susceptible drug a coat that resists decomposition in the stomach, allowing it to pass undissolved until it reaches the intestinal tract. There are also slow-release forms that may be prescribed to prolong the effect of a particular drug or allow it to be given on a once- or twice-daily regimen.

With age, the pH of gastric juice increases (becomes less acidic), the stomach's emptying time is longer, the gastrointestinal wall becomes thinner, and there is some loss of the absorptive and transporting epithelium. All of these conditions may exert an effect on a drug's chemical dissociation phenomena and alter the rate of its absorption. While these age-related changes are of theoretical interest, there is no compelling evidence that they exert a meaningful effect on drug absorption from the gastrointestinal tract or have clinical significance for the elderly patient.

Drug Distribution

Drugs enter the circulating blood by injection or after absorption from the gastrointestinal tract and begin a process of distribution into the fluids within and between cells of body tissue, two of several so-called compartments of the body. The distributed drug goes first to various bodily organs in proportional amounts: the amount of drug an organ receives is determined primarily by the amount of blood it receives. The brain, kidney, liver, heart, and other well-supplied major organs receive most of the first few minutes' dispersion, but within the following minutes to hours, the viscera, muscle, fat, and skin are infused to the same general level. This early phase of drug distribution is a function of cardiac output and blood flow and may be diminished or prolonged by the reduced output of a diseased or aging heart. Another important factor is the drug's solubility. Lipid-soluble drugs that cross biological membranes will easily be more widely distributed than non-lipid-soluble ionized ones. Except for small elemental ions, such as lithium, most biological membranes are impervious to ionized drugs.

During the time they are within the vascular system, many drugs are bound to circulating blood proteins, leaving only the unbound portion of the drug free to diffuse into tissues, other compartments and, ultimately to the target site of its action, the drug's receptor. The binding of drugs to these proteins imposes a limit on the circulating drug's availability for further distribution and the speed with which it reaches its intended site of action. The bound drug is in a dynamic equilibrium with the unbound drug population and is released from binding as the unbound portion is diminished as a result of its leaving the circulation to be further distributed, metabolized, and excreted. The more strongly bound the drug, the less accessible it is for distribution to cells and other body compartments outside the vascular system. In the case of a strongly bound drug, the drug's pharmacological action may be restricted and its metabolism and excretion slowed. There may be an age-related decrease of the blood proteins that bind the drugs, resulting in a smaller bound portion of the circulating drug and a larger portion of it in the unbound state. **Figure 1** demonstrates this phenomenon, comparing the bound:free ratio for a hypothetical drug in a young adult to that in an older patient. Since the unbound portion is that part of the dose that carries out its effects, a small alteration in the amount of unbound drug may cause a large percentage change in the functional dose of the drug, and is one mechanism postulated to underlie an increase in drug sensitivity and adverse effects in the elderly.

Drug distribution is further influenced by the small differences in pH between fluids inside and outside the cells. A drug rendered more lipid soluble by the slightly higher pH of the extracellular fluid might

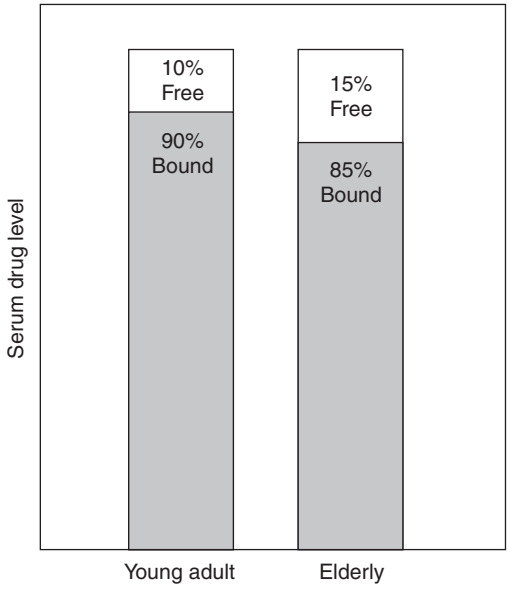

Figure 1 Percentages of a hypothetical drug's molecules circulating free and bound to plasma proteins, comparing a young adult and an elderly patient. In comparison to the young adult, the elderly patient has a lower concentration of blood proteins to bind the drug, leaving a greater percentage of the circulating drug unbound. Note that a 5% increase in the unbound portion represents a 50% increase in this, the functional portion of the circulating drug.

easily traverse the cell membrane but become less lipid soluble in the lower pH of the intracellular fluid and could not then easily diffuse out of the cell. In this manner, the drug could accumulate in a tissue: more would be entering than leaving its cells. Highly lipid-soluble drugs accumulate in fat tissues. Diffusion into tissues where the drug has no pharmacological activity is one of the body's drug inactivation processes, but may also affect drug action in other ways. An accumulation of a drug in a tissue or compartment may become a repository from which the drug, after its administration has been stopped, diffuses back into the general circulation and, in some cases, continues to act pharmacologically. For example, many highly lipid-soluble agents, such as phenothiazines, are stored in fatty tissues, and after chronic dosing can be detected in the patient's serum 6 months after the last dose. One of the highly lipophilic barbiturates given for anesthesia rapidly disperses from serum into the brain, where it acts quickly but transiently if given for only a brief period but becomes longer-acting after repeated or prolonged infusion causes saturation of fatty tissue storage sites. With the storage sites filled, this rapid diffusion/storage mode no longer predominates, and the slower processes of metabolism and excretion become the major mechanisms terminating pharmacological activity. The slower elimination results in continued circulating therapeutic levels and longer pharmacological activity for the barbiturate. This latter instance also illustrates how various pharmacological mechanisms, all of which must be taken into account and understood in the prescription of a medication, contribute to that medication's actions, side effects, and idiosyncrasies.

Only lipophilic drugs are able to diffuse from the blood into the central nervous system (CNS). Ionized compounds, on the other hand, are unable to breach the blood–brain barrier, a factor that must be considered in choosing an agent in particular clinical situations. Many drugs, sold over-the-counter or prescribed to the elderly, possess the ability to block the effects of the neurotransmitter acetylcholine in the CNS and the peripheral nervous system (PNS). Such drugs, commonly called anticholinergics, may in high doses cause delirium, agitation, and hallucinations (CNS symptoms); other effects may include tachycardia, constipation, and urinary retention (PNS symptoms). The elderly, who are particularly sensitive to these effects, may become poisoned by accidentally overdosing on such a drug or drugs and require emergency treatment. The antidote, physostigmine, which easily traverses the blood–brain barrier, will reverse all of the anticholinergic effects. Neostigmine, a strongly ionized congener of physostigmine, which does not enter the CNS, is sometimes mistakenly selected in such cases by the treating physician. In this situation, only the PNS symptoms are reversed. The patient would therefore continue to be delirious, hallucinated, and agitated until the mistake was discovered and physostigmine administered.

Drugs may accumulate in other cells, tissues, and fluids in sufficiently high concentrations to promote a reservoir effect as the plasma level of the drug decreases. For instance, some of the drugs bound to blood proteins may act as a reservoir when displaced from their binding sites by other drugs.

Drug Metabolism

Once a drug has been absorbed and distributed, the body begins processes to inactivate and eliminate it. How thoroughly and rapidly the body eliminates a drug is a strong determinant of that drug's duration of action, efficacy, and toxicity. In any given patient population, there are very large interindividual variations in the rate of these processes. These differences are frequently genetically based and constitute the subject of a rapidly developing subdiscipline called pharmacogenetics. A patient who metabolizes a drug rapidly would maintain a low circulating blood drug level and may require larger-than-usual doses for therapeutic effect. Another who metabolizes slowly, causing a higher-than-expected blood drug level, may become toxic on an average dose of the drug. These elimination processes begin immediately, and variations in their rate must be considered by the prescribing professional when formulating a therapeutic regimen for the individual patient. In most elderly patients these processes are slowed, and unless this fact is recognized and the usual daily adult dose modified to meet the special requirements of the elderly, the blood drug level may reach toxic amounts. For this reason, in order to reduce the incidence of adverse reactions, the dictum 'start low and go slow' is applicable when prescribing for the older patient. The physician must also monitor the patient carefully to ascertain that a therapeutic effect is obtained. After starting low, care must be taken to raise the dose sufficiently; unless therapeutic amounts are given, the drug may not reach adequate blood levels, exposing the patient to risk of adverse effects without providing therapeutic benefit.

Once in circulation, the drug is subjected to the degradative actions of a variety of bodily enzymes. Most of the enzymes that metabolize drugs are found in the liver, but several types are found in the kidney, lung, and gastrointestinal tract as well. Because most of the absorbed drugs are lipid soluble, they must first be converted to water-soluble forms in order to

be excreted by the kidneys. Lipophilic drugs, which diffuse easily out of the kidney and back into circulation, are conjugated with polar molecules provided by the host to make water-soluble products, which are then excreted in the urine. Other types of enzymatic actions result in altered forms, called metabolites, of the drug. These forms may be rendered pharmacologically inactive, but some have as much (occasionally even more) potency as the parent molecule. If the metabolite has pharmacological activity, it will be transformed further to an inactive form, conjugated, and excreted.

After absorption from the gastrointestinal tract, a drug enters the veins of the hepatic portal system and is transported to the liver, through which it must pass before entering the general circulation. Certain drugs are subjected to the combined effects of enzymes in the gastrointestinal wall and the liver, which may prevent a clinically significant amount of the drug from gaining entry to the general circulation. This is called the first-pass effect. While the water-soluble drugs are not well extracted by the liver, highly lipophilic drugs are avidly taken up and transformed. This first-pass process may be so efficient that only 5–10% of the drug dose will pass through into the systemic circulation. The term bioavailable describes that portion of the drug reaching systemic circulation, which then transports it to the site of action. The bioavailability of a drug that is highly extracted by the liver may be markedly increased by a modest reduction in the efficiency of this first-pass effect. Thus, if a drug ordinarily is 95% removed in this process, only 5% of the dose will become bioavailable. If the extraction value were to be reduced to 92%, bioavailability will increase by more than 50%. This would generally have the effect of administering a 50% larger dose of the medication to the patient. If not accounted for, this increase may result in serious side effects normally associated with drugs administered at much higher dosages. Physiological changes, which cause a reduction in this important hepatic function, are reported to occur in otherwise healthy people but are more prevalent, and are prevalent to a greater degree, in those elderly who are frail and with organs decompensated by disease. Many drugs prescribed for the older patient, particularly cardiovascular agents, are affected by these changes. Propranolol is a β-adrenergic blocking agent given for the treatment of cardiac arrhythmias and hypertension. The first oral dose of propranolol is almost completely removed by the extraction activity during its first pass through the liver. It is not until subsequent doses partially or completely saturate the degradative enzymes that sufficient unchanged drug passes through to the general circulation and raises propranolol to clinically effective blood levels. Even so, for propranolol, the average bioavailable amount is only 25% of the administered dose.

Upon extraction from the blood, the drug enters the hepatic cells, where the bulk of drug metabolism occurs in two steps (phase I and phase II). The liver enzymes (and other bodily enzymes as well), many of which are in the microsomal organelles within the hepatic cells, begin transformation of the drug by a variety of enzymatically catalyzed reactions that will determine its fate. The cytochromes P450 are a family of related forms (isoforms) of enzymes found primarily in the liver, with small concentrations in the intestinal wall and other tissues. Their important role (in phase I) is to help rid the body of toxins, including medications, through a process of oxidative metabolism. Other enzymes conjugate the medications in so-called phase II reactions. Both of these processes help convert lipid-soluble drugs to water-soluble ones so that they can be excreted through the kidneys. Not all of these enzymes act on all drugs, but each acts on many. When one enzyme is acting on two or more concomitantly prescribed medications at the same time, unanticipated drug interactions may occur. These include one drug slowing another's excretion, causing it to accumulate until it reaches the clinical equivalent of an overdose, or the first drug can hasten excretion of another, reducing its therapeutic action.

In phase II reactions (conjugation), the drug molecule or its metabolite is combined with another compound, usually a substance found naturally in the body, such as a carbohydrate, amino acid, sulfate, or acetic acid. These conjugations, also called synthetic reactions, commonly utilize the carbohydrate glucuronic acid, but other substances such as the acetyl and methyl molecules, glycine, and sulfate are extensively used. After conjugation, the lipid-soluble drug becomes water soluble and may now be excreted by the kidneys. Part of the dose is converted by a variety of other biochemical actions to inactive (or, for some, pharmacologically active) metabolites. Whether active or inactive, those metabolites that remain lipid soluble will be subsequently conjugated and excreted.

In addition to conjugative metabolism, liver enzymes subject drugs to multifarious other reactions. Oxidative metabolism, an important method for inactivating drugs, is performed by multiple enzyme systems, including heme peroxidases, amine oxidases, alcohol dehydrogenase, and xanthine oxidase. The largest group of oxidases, which are responsible for the breakdown of a multiplicity of drugs, are the cytochromes P450, found in organelles within

the cell. Many therapeutic agents induce or inhibit these enzymes, and a growing body of literature has elucidated important drug–drug interactions at this vector. The frequency with which multiple drugs are concomitantly prescribed to the older patient dictates that drug–drug interactions will inevitably occur.

Imipramine, a tricyclic antidepressant used to treat depression and anxiety states, is initially metabolized by oxidative removal of one of the two methyl groups from its side chain nitrogen, forming the pharmacologically active metabolite desmethylimipramine. This molecule is, in turn, further oxidized to its inactive 2-hydroxy metabolite, glucuronidated, and excreted. Other tricyclics undergo similar side chain demethylations, but with varying sites of oxidation of the ring structure before conjugation. Chlorpromazine, an antipsychotic given in the treatment of such conditions as schizophrenia and manic-depressive disorders, is transformed into as many as 26 different metabolites, some of which may be more toxic than the parent drug. It is possible that a patient whose enzymes idiosyncratically form more of the toxic metabolite would experience more toxic adverse effects than someone whose enzymatic systems transformed chlorpromazine mainly to other less toxic forms. Such variation in underlying enzymatic mechanisms might explain the wide differences in side effect profiles seen in patients treated with chlorpromazine.

Enzymatic chemical reduction of nitrogen atoms within the molecular complex of a drug, through addition of hydrogen to their azo and nitro forms, is another inactivation pathway. Other metabolic enzymes destroy certain drugs by the process of hydrolysis. Physostigmine, which enhances central and peripheral cholinergic action by preventing the breakdown of the neurotransmitter acetylcholine, is itself hydrolyzed at its ester linkage by cholinesterase enzymes. Breaking the ester linkage splits the physostigmine molecule, ending its pharmacological action. This process is rapid: most of an administered dose of physostigmine is inactivated in 2 h.

While activity of drug-metabolizing enzymes is a consistent determinant of drug action, there are a variety of chemicals that enhance or retard their ability to act on particular drugs. Enhancing an enzyme's effect is commonly called induction. Increasing the quantity of a drug-metabolizing enzyme increases its actions and reduces the amount of the circulating drug. Inhibition of an enzyme reduces its degradative activity, resulting in higher blood levels of the drug. Chemicals that inhibit or induce the biochemical activity of the enzymes include other medications, toxins (including nicotine), and ethyl alcohol. Such agents given before or during a drug's administration might cause an acceleration or diminution of that drug's metabolic breakdown, thus raising or lowering the anticipated blood level. Since the broad range of enzyme-inducing and -inhibiting agents includes many commonly prescribed medications, the responsible physician must give cognizance to these interactions when recommending more than one drug at a time for any patient, but especially the more vulnerable older patient. Physiological changes, such as age-related shrinkage of liver mass and reduction in hepatic blood flow, also affect drug metabolism. Reducing hepatic blood flow reduces the amount of circulating drug presented for uptake into the liver cells, whereas loss of liver mass would reduce the amount of that organ's enzymes available for action.

Drug Excretion

The end point of the foregoing operations is the elimination of the administered drug from the body. The final pathway for elimination is the process of excretion, which is conducted mainly by the kidneys, with several other organs and routes playing less significant roles. Orally administered drugs that have not been absorbed or that have been excreted into the intestine in bile are passed out with the feces. Drug metabolites formed in the liver may be excreted into the intestine through the biliary tract and are reabsorbed to be excreted by the kidneys or pass with the feces. Excretion by the lungs is limited almost exclusively to gases and volatile agents. Excretion through tears, sweat, and saliva is relatively insignificant. Salivary drug levels may correlate well with plasma levels (and are sometimes used to measure a drug's concentration when other body fluids are not available); they are generally swallowed and reabsorbed, and only a miniscule amount is excreted.

The excretory function of the kidney involves three intrinsic processes of its nephron: filtration of drugs through the glomeruli, secretion through the tubules, and passive reabsorption into the tubular cells. In the service of maintaining the narrow limits of the body's internal milieu, the kidney is very active in the excretion and reabsorption of a variety of molecular materials, including water and electrolytes, body wastes, and foreign compounds such as drugs and poisons. Once filtered, the fluid containing the drug and/or its metabolites enters the renal tubules, where the metabolites may be reabsorbed or pass into the urine. For a drug to be readily excreted by the kidneys it must be water soluble. This most important variable determines that lipid-soluble drugs must be rendered polar (water soluble) before they will be excreted into the urine. A non-polar (lipid-soluble)

drug, particularly a weak acid or a weak base, in the glomerular filtrate will be almost completely passively reabsorbed through the cells of the proximal and distal tubules of the nephron. The sum total of filtration, reabsorption, and excretion determines the renal clearance of a drug. How tightly bound the drug is to blood proteins also affects its renal excretion, because the bound portion is not readily available for glomerular filtration, and lowers its renal clearance rate. Because tubular cells are not as permeable to ionized drugs as to the un-ionized ones, passive reabsorption of water-soluble drugs becomes dependent in part on the pH of the tubular fluid. In the presence of a more alkaline tubular fluid (higher pH), weakly acidic drugs are more ionized and more rapidly excreted. The opposite occurs when the tubular urine is more acidic (lower pH): a weak acid would remain un-ionized and more readily reabsorbed. For weakly basic drugs, the converse of these conditions would hold true: their excretion would be enhanced in the more acidic tubular fluid but inhibited in the presence of a more alkaline fluid.

Clinicians sometimes take advantage of this renal physiology by manipulating urine pH to accelerate the excretion of a drug that may be present in moderate overdose or causing unwanted effects. Drugs such as ammonium chloride render the urine more basic; ascorbic acid causes a more acid urine. This principle would be salutary in the management of toxic levels of such drugs as a salicylate (i.e., aspirin). Raising urinary pH (rendering it more alkaline) will accelerate elimination of the salicylate in the older patient without having to resort to invasive measures, such as renal dialysis. In order for this treatment to be effective, however, the change in pH must be made to persist until the drug blood level is reduced. An overdose that is very large or life threatening would, of course, be treated by more heroic measures, such as renal dialysis and other appropriate supportive therapy.

An important measurement of a drug's kinetics is its serum half-life (also called half-life and elimination half-life), determined by serial measurements of the drug's blood level after a single dose, and often indicated by the symbol $T_{1/2}$. As illustrated for a hypothetical agent in **Figure 2**, a drug's half-life is defined as the time required to reduce its blood level to one-half of its single-dose peak blood level. The data obtained from the time required for the rise and fall of a drug's blood concentration also reflect rates of its distribution, bioavailability, and clearance. From these data, the pharmacologist can infer how long the drug remains in blood after an acute dose, how much time is required to reach a steady-state level, and how long the drug will remain in the blood after the last dose. The length of time the drug stays in the blood is a function of its clearance, which is a corollary of all the mechanisms previously discussed. Because it is multifactorally determined, the drug's half-life cannot be used alone as the only measure of its disposition or to specify an alteration in any one of the bodily functions that subserve it.

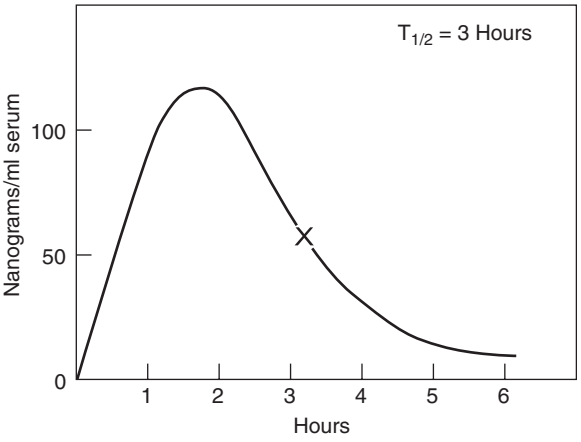

Figure 2 Illustration of the derivation of a drug's serum half-life. In this depiction an oral dose of a hypothetical drug was given at time 0. The drug's blood level rises to a peak of 100 ng/ml of serum. As it is distributed, metabolized, and excreted, its blood level falls. The drug's half-life ($T_{1/2}$) is considered to be the time required for its serum level to reach one-half its peak value. Here, one-half of the peak value (denoted by the X in the downslope) is reached in 3 h.

When a drug's dose is repeated and each subsequent dose is given at an interval approximating its elimination half-life, the drug will accumulate, its blood level will rise, and a steady-state blood level will build. In between each dose, the drug's blood concentration rises and falls, with the steady-state level usually being calculated at a midpoint between the upper and lower blood level values from the individual doses. At the point where the amount of drug entering into the blood equals the amount being eliminated, a steady-state level is attained. Note that **Figure 3** demonstrates that the time required to reach a steady-state level is approximately four of the drug's elimination half-times. When drug blood levels are reported for the usual clinical practice situation, it is the steady-state value that is used. Many drugs have a therapeutic window, by which is meant that there is a steady-state blood level below which it will not be effective, and a level above which it is toxic, with a mid-range wherein it will exert its therapeutic effect with minimal or no toxicity. **Figure 4**, shows the therapeutic window for a hypothetical drug as the shaded area. When a therapeutic window has been established for a particular drug, the physician is able to utilize this information and

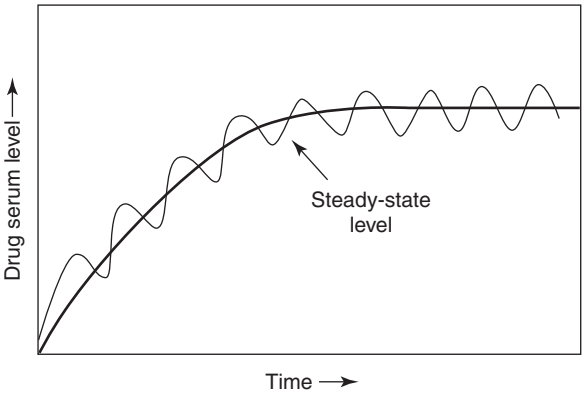

Figure 3 In this illustration repeated oral doses of a hypothetical drug are given beginning at time 0. Subsequent doses are given at approximately the drug's elimination half-life, resulting in a rising drug blood level. In between each oral dose, the drug's blood level rises and falls. At a time between four and five times the drug's half-life, its serum level reaches a steady state. The unwavering line represents the rise of the drug's serum level to steady state during intravenous administration.

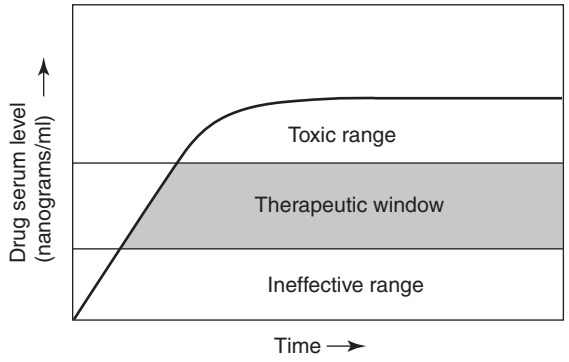

Figure 4 Illustration of a drug's therapeutic window. As a drug's serum level rises, it reaches a value at which it becomes therapeutically effective. As the level continues to rise, it remains effective until it reaches a value above which it begins to exert effects more toxic than therapeutic. The range of the drug's serum level values between the ineffective and the toxic is called the drug's therapeutic window.

determine from one drug blood level value whether or not the patient's blood level is too high or too low before ordering adjustments in the dose. For many drugs, laboratories have established ranges of drug blood level values to assist the physician in adjudging adequacy of the therapy. In elderly patients, many of whom have reduced tolerance to adverse drug effects, it may be difficult to differentiate whether worsening symptoms are due to the primary disease or adverse drug effects. In such cases, drug blood levels may be discriminatory and of definitive clinical value. These same kinetics apply to drugs given intravenously: the blood drug level will rise and reach a steady state at approximately four of its elimination half-times, though the accumulation will be smoother and not show the fluctuations characteristically seen with orally administered doses.

Blood level data and knowledge of a drug's pharmacokinetics may be especially valuable when its therapeutic effects are difficult to judge from observation, its dose must be raised quickly as a treatment necessity, or it has a very narrow dose range (i.e., when there is a small range of values between its therapeutic and toxic levels). Though not foolproof (the patient can go off the medication and restart it shortly before the blood sample is drawn), blood levels offer one of the most reliable methods for ascertaining the patient's compliance with the prescribed medication. Lithium, an important agent in the treatment of affective disorders, has a narrow therapeutic range. In treating a patient with a manic-depressive disorder that has persisted into old age, the physician may order repeated serum lithium levels early in the therapy to establish the oral lithium dose required to maintain the blood level between 0.5 and 1.4 mEq/l serum. Such monitoring is necessary in all patients, but is especially important in the older patient, who may have a reduced renal clearance for lithium. Even if given a lower than usual starting dose, an elderly person can quickly accumulate toxic levels of this ion, making regular blood level determinations mandatory.

Pharmacodynamics

Pharmacodynamics is concerned with drug effects and the body's physiological and biochemical mechanisms through which the drugs exert these effects. Pharmacodynamic data are derived from studies of drug receptor sites, cellular activity, intracellular mechanisms, and structure–activity relationships of the drug itself. Though cellular, molecular, and clinical pharmacology are contributing to a growing body of research in pharmacodynamics, there remains a paucity of data specific for the elderly subpopulation in this area.

Drugs typically begin their pharmacological activity by interacting with a cell at specialized proteins called receptor sites, in its plasma (outer cell wall) membrane, or on channels in the membrane through which ions pass in and out of the cell. They may also act on receptors within the cell or on other proteins or chemical moieties that comprise intracellular mechanisms. The cell wall receptors are typically agonized or antagonized by a variety of endogenous substances (called agonists and antagonists), which transform the receptors, sending a signal into the cell, and stimulation or inhibition of the cell's activity. Drugs are designed to mimic, exaggerate, or interfere in some way with the body's own physiologically

active substances (ions, transmitter substances, enzymes, hormones). Stimulation of a cell's receptor site typically causes a cascade of intracellular events that embrace a multiplicity of mechanisms and lead ultimately to cellular activity (e.g., signaling another cell, contraction, secretion of a substance, or genetic activity).

There is an age-related decrease in some types of receptor sites and a decrease in physiologic cellular and organ activity. These changes may lead to altered sensitivity to medication effects. While there is evidence of an age-related decrease in sensitivity to many medications, some, such as the anticoagulant warfarin, may show an increased effect in the older patient. In general, the elderly are more susceptible than younger patients to the adverse events attendant on drug therapy. Because there is no silver bullet, drugs all act at multiple sites and cause multiple and often unwanted effects, in addition to their action at the target site. Thus, an antidepressant given to treat depression in an elderly patient would cause the downregulation of the β-adrenergic receptor as part of its antidepressant effect. At the same time, it antagonizes the muscarinic cholinergic receptors, producing urinary retention, constipation, dry mouth, blurred vision, and such a degree of discomfort to the patient as to merit stopping the drug, despite its salutary action in lifting the patient's depression.

Drug Interactions and Side Effects

The physician must individualize the elderly patient's therapeutic regimen. Appropriate therapy for the elderly includes careful consideration not only of pharmacokinetics but also of pharmacodynamics. Since the elderly patient is often administered multiple drugs, the physician must note that significant interactions can and will occur. Such interactions can occur during any phase of pharmacokinetic processes, but most of these occur in the process of elimination. The elderly are particularly sensitive to the effects of blocking the body's ubiquitous muscarinic cholinergic receptors. Antimuscarinic actions are therapeutically useful in instances such as relaxing spasmodic smooth muscle (i.e., intestine, urinary bladder) or for parkinsonism, but they are more commonly encountered as unwanted side effects. The US Pharmacopeial Drug Information (USP DI) Review includes a selected list of more than 50 drugs that possess antimuscarinic activity in addition to their primary therapeutic actions. In a regimen of polypharmacy, the side effects of several drugs may be interactive and additive, further slowing an age-related gastrointestinal tract hypomotility, causing severe constipation. Drug-induced urinary retention, even when mild, is problematic for all older patients but can become emergent in the elderly male, who may require prompt catheterization due to a prolonged inability to void. **Table 1** lists several of the more prominent signs and symptoms associated with antimuscarinic effects (often synonymously called atropinic or anticholinergic effects). In addition, the restlessness, delirium, and hallucinations may be misdiagnosed as a psychiatric illness. Prescription of a psychiatric drug, nearly all of which possess inherent antimuscarinic properties, may be contraindicated in such an instance because they may additively aggravate this critical drug-induced situation.

Table 1 Antimuscarinic effects[a]

Blurred (near) vision
Urinary retention
Constipation
Dry mouth
Thirst
Decreased sweating
Tachycardia
Palpitation
Restlessness
Delirium
Hallucinations

[a] A partial list of effects caused by blocking the muscarinic receptors of the various body organ systems. These are also referred to as anticholinergic or atropinic effects. Some of these effects, especially the bottom three, may be misdiagnosed as a psychiatric illness.

Though many drug–drug interactions have been identified by experiential observation and careful clinical pharmacological research, there is a potential for many others among the hundreds of prescription agents and over-the-counter remedies available to the elderly. Some representative examples include the following:

1. The antibiotic neomycin can abolish intestinal bacteria that are responsible for the metabolic transformation of certain drugs. Without these bacteria, the ingested drug in question would not be metabolized at its usual rate and its pharmacological actions may be reduced, or greater than expected. Drugs such as L-dopa, salicylazosulfapyridine, and digoxin are examples of agents affected in this manner.
2. Ion exchange resins (administered to reduce blood cholesterol levels) and gel antacids physically adsorb many concomitantly administered drugs and may thereby reduce or delay their absorption.
3. Guanethidine, an antihypertensive, must be taken up by the adrenergic neuron's norepinephrine

reuptake pump in order to reach its site of action. Drugs that block this pump, such as tricyclic antidepressants and phenothiazines, prevent the uptake of guanethidine and antagonize its antihypertensive actions.

4. Ethyl alcohol is involved in multiple interactions and may variously affect the pharmacology of other drugs through such actions as delaying gastric emptying time, changing gastric pH, delaying drug absorption, or denaturing the drug itself.
5. Probenecid inhibits the renal tubular secretion of penicillin and is often used in a therapeutic interaction to raise the blood level of this antibiotic.
6. Metabolic breakdown of the oral hypoglycemic tolbutamide is inhibited by sulfaphenazole. This interaction raises the blood level of tolbutamide, causing hypoglycemic attacks in patients whose diabetes had been well controlled before the second drug was given.
7. Dicoumarol, an oral anticoagulant requiring careful attention to proper dosing and frequently prescribed to elderly patients, is subject to interactions with a variety of other drugs. Drugs that accelerate its metabolism would lower dicoumarol's blood level and reduce its therapeutic action. A drug that inhibits dicoumarol's metabolism would raise its blood level and increase its therapeutic effects.

The extent of potential problems caused by unwanted effects of prescription drugs may be inferred by reference to the USP DI Review, which lists, in addition to anticholinergically active drugs, an extensive (but not inclusive) compilation of medications that may cause other problems as well. These adverse reactions include such categories as blood dyscrasia, blocking thyroid function, depressing the bone marrow, depressing the central nervous system, stimulating the CNS, inducing hepatic P450 enzymes, inhibiting various hepatic enzymes, extrapyramidal reactions, antagonizing folic acid, hemolysis, hepatotoxicity, hyperkalemia, hypokalemia, hypotension, hypothermia, methemoglobinemia, nephrotoxicity, neurotoxicity, ototoxicity, and blood platelet aggregation. Each of these categories contain from approximately 20 to more than 50 prescription drugs, making it probable that the elderly patient will have some exposure to the potential hazards. Information such as this on prescription medications is regularly disseminated in the USP publications, as well as in continuing medical education forums sponsored by various medical institutions, and is available to professionals and others who care for the elderly.

See also: Brain and Central Nervous System; Gastrointestinal System: Function and Dysfunction.

Further Reading

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Physical Therapy and Rehabilitation

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Glossary

Disability – Patterns of behavior emerging over long periods of time in which an individual experiences functional limitations that can not be overcome for normal role and task performance.

Disease – An ongoing pathological state that is delineated by a particular cluster of signs and symptoms and is recognized externally by either the individual or a practitioner as abnormal.

Functional Activity – A self-referenced concept dependent on what an individual identifies as essential

to support physical, psychological, and social well-being as well as to create a personal sense of a meaningful life.

Impairment – Evolves as a consequence of disease, and can be defined as alterations in anatomical, physiological, or psychological structures or functions.

Physical Rehabilitation – The practice of promoting changes in an individual, by altering his or her physical or social environments, or by implementing a combination of both strategies to return the individual to as close to the premorbid level of function as possible or to maximize a person's current potential for function and to maintain it for as long as possible.

Introduction

The overarching goal of physical rehabilitation is to return the individual to as close to the premorbid level of function as possible or, alternatively, to maximize a person's current potential for function and maintain it as long as possible. This goal is achieved by promoting changes in the individual, by altering his or her physical or social environments, or by implementing a combination of both strategies. For an otherwise healthy older patient with a simple wrist fracture, rehabilitation may be a reasonably straightforward process. However, considering the necessary steps to return a frail patient following a stroke to a previous, and often tenuous, level of prior function as an example, the rehabilitation program is much more complex because the problems are much more extensive, complicated, and interwoven. Every individual values the ability to function independently and live as he or she chooses. Functional activities, in a gerontological frame of reference, encompass all those actions, tasks, activities, and roles that identify a person as an independent adult.

Although discourse on rehabilitation can often be focused on the extensive and comprehensive efforts necessary to assist an individual who has experienced multisystem impacts and global loss of function from a particular illness, injury, or incapacitation, there are also many active older persons who benefit from less intensive services, including prevention, provided by particular rehabilitation specialists to maintain a desired level of function and quality of life. Thus, rehabilitation services cover multiple dimensions of health service delivery, from simple to complex patient needs, from single provider to comprehensive multidisciplinary teams, and from outpatient private and ambulatory clinics to hospital- or facility-based programs. However, all rehabilitation efforts share the same emphasis on care over cure regardless of complexity or setting and a commitment to mitigating the diminution of function whether it is due to changes associated with the aging process or to some specific disease, disorder, or injury.

Relevance of Rehabilitation to Aging

Functional activity is a self-referenced concept and is dependent on what an individual identifies as essential to support physical, psychological, and social well-being as well as to create a personal sense of a meaningful life. Certain categories of activities are common to everyone: eating, sleeping, dressing, elimination, and hygiene. Locomotion (most typically walking), complex hand activities, and communication are essential underlying components of higher-order tasks and activities, such as cooking, shopping, housecleaning, household chores, and using transportation that can be crucial to living independently in the community. Many older persons also engage in work and volunteer activities as well as recreational activities that require a high degree of functional ability. Loss of function will generally increase with aging and tends to be more prevalent among women at every age, and may also reflect racial disparities in health status. Reported differences in functional status between men and women are a reminder that function is also a sociological phenomenon that depends on what is normal functioning for an adult filtered through social, ethnic, and cultural expectations.

Unique Aspects of Geriatric Rehabilitation

The proportion of elderly at any age without any chronic conditions is small, and disease can trigger a cascade of events resulting in functional deficits and disability. An increase in the number of activities with which an elder has difficulty increases linearly with comorbidity, that is, coexistent medical conditions that further complicate not only the genesis of a functional deficit but also its treatment. For example, rehabilitation for a stroke for an individual who also has painful, degenerative changes in the foot and a low tolerance for stressful activity secondary to angina with exertion would present a particular rehabilitation challenge. Yet, this example encapsulates the rehabilitation specialist's emphasis on care and function, not cure and disease.

Traditionally, geriatric researchers and clinicians have focused on the pathological changes associated

with normal aging, while ignoring a substantial proportion of elders who do not exhibit these changes. Thus, normal aging has been broadly and erroneously equated with pathological aging. Although no one will escape the ultimate eventuality of disease, disability, and death, many older persons are able to decrease their overall morbidity and delay the onset of disability. Moreover, many older persons continue to function with a high degree of independence, even in spite of their chronic conditions, and enjoy an overall positive quality of life. Rehabilitation specialists assist older persons in obtaining an enhanced quality of life by encouraging modification of some lifestyle factors such as diet and exercise in addition to their more traditional concentration on interrupting a vicious cycle of disease, disability, new incident disease, new incident disability among older persons.

Rehabilitation also plays an important role in an emergent subpopulation among aging individuals. Not all disability is acquired in later life. Due to advances in medicine and in rehabilitation throughout the life span, individuals with developmental disabilities as well as people who experience disability from a disease or injury earlier in life are now living well into old age.

The Principles of Rehabilitation

There are two conceptualizations of the relationships among disease and disability that help elucidate rehabilitation practice. The first, sometimes referred to as describing the process of disablement, was first articulated by Nagi and elaborated upon by the Institute of Medicine (IOM), which then later conjoined the concept of disablement with a description of a process of enablement. In this model, health status is parceled out into four distinct components that evolve sequentially as an individual loses well-being: disease or pathology, impairments, functional limitations, and disability. Subsequently, the model identifies the degree to which the physical or social environment contributes to disablement or its opposite, i.e., how these environments enable function. Taken together, these concepts describe the essential elements of an overall framework for examination, diagnosis, and treatment in rehabilitation.

In the Nagi/IOM model, the term disease refers to an ongoing pathological state that is delineated by a particular cluster of signs and symptoms and is recognized externally by either the individual or a practitioner as abnormal. Disease may be the result of infection, trauma, metabolic imbalance, degenerative processes, or other etiologies. The second term, impairment, which evolves as the consequence of disease, can be defined as alterations in anatomical, physiological, or psychological structures or functions. Physical impairments, such as pain and decreased range of motion in the shoulder, may be the overt manifestations (or symptoms and signs) of either temporary or permanent disease or pathological processes. While most individuals anticipate that anatomical and physiological systems will deteriorate with time as they age, an inability to do things for themselves from day to day perhaps most clearly identifies when older persons are losing their health. Nagi proposed that functional limitations were the results of impairments and consisted of an individual's inability to perform the tasks and activities that are typical for that individual, for example, reaching for something on an overhead shelf or being able to dress without assistance. As measures of behaviors at the level of a person, and not anatomical or physiological conditions, limitations in functional status should not be confused with diseases or impairments that encompass aberrations in specific cells, tissues, organs, and systems that present clinically as an individual's signs and symptoms.

Functional limitations occur in distinct categories of tasks and activities: physical, psychological, and social. Physical function covers an individual's sensorimotor performance in the execution of particular actions, tasks, and activities. Rolling, getting out of bed, transferring, walking, climbing, bending, lifting, and carrying are all examples of physical functional activities. These sensorimotor functional abilities underlie the fundamental daily organized patterns of behaviors that are further classified as basic activities of daily living (ADLs), such as feeding, dressing, bathing, grooming, and toileting. The more complex tasks associated with independent community living, for example, using public transportation or grocery shopping, are categorized as instrumental ADLs, often abbreviated as IADLs. Successful performance of complex physical functional activities, such as personal hygiene and housekeeping, typically requires integration of cognitive and affective abilities as well as physical ones.

Psychological function has two components: mental and affective. Mental function covers a range of cognitive activities such as telling the time and performing monetary calculations that are essential to living independently as an adult. Attention, concentration, memory, and judgment are all elements of mental function. An elder's emotional state and effectiveness in coping with the stresses attributable to disease or negative impacts of the aging process are indicators of the patient's affective function. Affective function broadly refers to both the everyday hassles of daily existence that are part of every elder's experience and the more traumatic events such as

death of a spouse. Self-esteem, anxiety, depression, and coping are also represented in the construct of affective functioning.

Social function encompasses an individual's social interactions and activities such as church attendance or family gatherings as well as performance of personally valued social roles and obligations. Many opportunities for social interaction for older persons occur around volunteer and leisure activities. Grandparenting and being employed outside the home are two examples of social role functioning relevant to an older individual.

The term disability denotes patterns of behavior that emerged over long periods of time during which an individual experienced functional limitations to such a degree that they could not be overcome to create some semblance of normal overall role and task performance. Thus, the concept of disability includes deficits in the performance of ADLs and IADLs that are broadly pertinent to many social roles. The person with limited shoulder motion who is fully able to bathe independently by using the range of motion available at other joints to best mechanical advantage and a shower mitt cannot accurately be described as disabled, even though functional performance may be extremely limited without the use of an altered movement pattern and an assistive device. Although each of the terms that have been presented so far involves some consensus about what is normal, the concept of a disability is socially constructed. Disability is characterized by discordance between the actual performance of an individual in a particular role and a set of expectations about what is normal for an adult, i.e., expectations that a task or activity should be accomplished in ways that are typical for an elder's age and sex as well as cultural and social environment.

Unfortunately, identifying a person as being in a particular state of discrepancy between performance and expectation can quickly slip into prejudicially labeling individuals as being disabled as if disability were a merely personal attribute and not the net result of an interactive state between person and environment. Impairment does not always entail functional limitation. One cannot assume that an individual will be unable to perform the tasks and roles of usual daily living solely by virtue of having impairments. For example, an elder with osteoarthritis (disease) may exhibit loss of range of motion and strength (impairments) and experience great difficulty in activities such as bathing (function). Rehabilitation will assist the individual to take a bath without any difficulty, perhaps by increasing strength, using available joint motion to the best advantage, or using assistive devices. The IOM elaboration of the Nagi model, as well as an alternative model, the International Classification of Function (ICF) developed by the World Health Organization, draws attention to the critical interaction between the person and the environment that either disables or enables an individual's function. Disability depends on the capacities of the individual, the suitability of the physical environment, and the expectations that are imposed on the individual by those in the immediate social environment, most often the patient's family and caregivers. The ICF model in particular also calls attention to the critical impact of attitudes and public policy in imposing or eliminating barriers to the full realization of an individual's potential to participate fully in society.

Functional Assessment

The cornerstone of rehabilitation practice is functional assessment. Analysis of function focuses on the identification of pertinent functional activities and measurement of an individual's ability to successfully engage in them. In essence, functional assessment measures how a person does certain tasks or fulfills certain roles in the various dimensions of living described previously. Functional assessment is accomplished through the application of selected tests and measures that yield data that can be used as (1) baseline information for setting function-oriented goals and outcomes of intervention, (2) indicators of a patient's initial abilities and progression toward more complex functional levels, (3) criteria for placement decisions, for example, the need for inpatient rehabilitation, extended care, or community services, (4) manifestations of an individual's level of safety in performing a particular task and the risk of injury with continued performance, and (5) evidence of the effectiveness of a specific intervention (medical, surgical, or rehabilitative) on function. Functional assessment in physical rehabilitation closely examines mobility, basic ADLs, IADLs, work, and recreation.

Mobility

A primary goal for performing a physical functional assessment of an elderly individual is to identify any functional limitations in mobility: ambulation on level surfaces within the home, stair climbing, negotiating uneven terrain, and walking for longer distances in the community.

Basic ADLs

Basic ADLs include all of the fundamental tasks and activities necessary for survival, hygiene, and

self-care within the home. A typical ADL battery, which may be administered by a physical therapist alone or cooperatively with other health professionals, covers eating, bathing, grooming, dressing, bed mobility, and transfers. Incontinence and the ability to use a bathroom are especially important elements in the assessment of physical function in some older individuals. The ability of an elder in three aspects of toileting, to get to the bathroom in an appropriate period of time, to move safely on and off the receptacle, and to perform self-hygiene tasks, may each require exploration.

IADLs

An examination and evaluation of IADLs addresses multiple areas that are essential to living independently as an adult: cooking, shopping, washing, housekeeping, and ability to use public transportation or drive a car. For some individuals, it may also be appropriate to investigate the ability to perform home chores such as shoveling snow or doing yard work.

Work

One measure of adult competence is employment. Older persons who want to, or need to, remain in the work force may do so if they are physically able to perform the tasks of their employment. The ability to work may be investigated in two ways. One approach is to consider the conditions of work itself: whether an individual is working the anticipated number of hours each week, whether the requirements of the job have been modified in any respect to allow the individual to work, and whether the quantity or quality of work done has met the anticipated standard of performance. Another approach to assessing work is to examine the ability to perform particular physical tasks, such as walking long distances; sitting or standing for several hours at a time; stooping, crouching, or kneeling; reaching up overhead; and lifting or carrying various weights.

Recreation

Recreational activities are no less important than work to maintain a sense of well-being. Clearly, older men and women today are maintaining interests in recreational sports that they developed earlier in life. Other elders are just discovering the pleasures of physical exertion. Functional assessment of recreational activities, however, is not limited only to sports. Many elders enjoy dancing and gardening, which require a relatively high degree of balance, flexibility, and strength. Even sedentary activities, such as stamp collecting or playing chess, require a certain degree of physical ability in the hand and upper extremity and therefore may be functional measures of the outcomes of intervention for some patients.

The Process of Rehabilitation

Although rehabilitation may be presented as part of a continuum of health-care services initiated after an acute admission, rehabilitation efforts may actually begin concomitantly with attempts to diagnose and treat the acute condition. While it is logical to assume that rehabilitation should not destabilize the condition of an acutely ill person, efforts to remobilize and promote even very low levels of function may, in fact, assist recuperation and prevent secondary complications. When attention turns toward planning a rehabilitation intervention, a cascade of questions is presented to the rehabilitation team. Of the impairments that are related to the patient's functional limitations, which ones can also be remediated by treatment? Furthermore, if the patient's impairments cannot be remedied, can the patient compensate by using other abilities to accomplish the task, and can the task or environment be adapted so that it can be performed within the restrictions that the patient's condition imposes on the situation? The strings of responses that emerge from this process highlight the process of enablement and encapsulate the rehabilitation specialist's approach to stopping or retarding the process of disablement. Even though many patients will make a full recovery even in the face of substantial functional loss and disability, the emphasis of rehabilitation is turned away from curing the disease that triggered the process of disablement and toward establishing a program of rehabilitative care that enables the highest level of function and quality of life possible.

The Rehabilitation Team

Rehabilitation is a collaborative effort that requires an effective synthesis of the knowledge and skills of multiple medical and health professionals to address the multiplicity and magnitude of problems presented by the patient with complex functional deficits resulting typically from disease or injury as well as the expected complications of aging. Therefore, rehabilitation usually requires a team effort to bring together a substantial division of labor to achieve its comprehensive goals. However, the practice of rehabilitation is perhaps unique in that the patient is regarded as a principal collaborator on the rehabilitation team, as rehabilitation specialists strive to implement their plans of care with the person rather than perform interventions on the patient.

The Core Multidisciplinary Team A physician with specialty training in geriatrics or rehabilitation

medicine often formally heads the rehabilitation team, especially in inpatient settings, and is responsible for all the medical needs of the patient. However, coordination of care is generally managed by nurses, often with advance practice credentials. Physical therapists, occupational therapists, and speech-language pathologists provide the three core rehabilitation benefits established by statute under the Medicare program. Social workers typically round out the team and assist in psychological adjustment to illness, social support issues, financial situations, and continuing care and discharge placement needs.

The Extended Team Depending on the specific needs of the patient, the core team may expand to add the services of additional professionals enlisted to accomplish particular goals, including orthopedic surgeons, neurologists, psychiatrists, psychologists, dentists, podiatrists, dieticians, audiologists, recreation therapists, orthotists and prosthetists, and vocational rehabilitation counselors.

Specific Therapy Services

Beneficiaries of the Medicare program have three rehabilitation-related benefits established by federal statute: physical therapy, occupational therapy, and speech-language therapy. All therapists, who must be graduates of accredited programs, must pass a national examination and be licensed, certified, or registered in their respective professions within the state in which the services are furnished. Medicare covers services that are necessary and likely to result in improvement in a reasonable period of time. Medicare does not currently regard prevention services provided by therapists as falling under therapy benefits and will not cover services intended to maintain a current level of function.

Physical Therapy Physical therapists target their interventions at restoring or maintaining physical function and health, especially as related to movement, and treating or preventing impairments and functional limitations that result from particular diseases or injuries. Impairments of strength, flexibility, and endurance, especially because they limit movement and diminish functional abilities such as gait and locomotion, are specific concerns in the physical therapist's plan of care. The primary forms of intervention used by physical therapists are therapeutic exercise, neuromuscular re-education, manual therapy, and functional training, as well as instruction and training targeted toward prevention. A growing number of physical therapists are credentialed in geriatrics through the American Board of Physical Therapy Specialties.

Physical therapy is sometimes erroneously used interchangeably with physical rehabilitation. Although physical therapy services account for the bulk of rehabilitation provided under the Medicare program (over 70% of all Medicare payments for rehabilitation), physical therapy is a distinct service provided by a particular health professional who is licensed and regulated as a physical therapist under state law. Similarly, physical therapy is often mistakenly regarded as synonymous with an array of interventions that use physical means to achieve a therapeutic goal. There are a number of health-care professionals as well as other kinds of practitioners who use physical agents (e.g., heat, cold, sound, and electricity) and mechanical modalities (e.g., traction) whose services are often incorrectly referred to as physical therapy.

Occupational Therapy Occupational therapists concentrate their attention on a patient's ability to perform all ADLs and IADLs independently, especially in light of perceptual or cognitive deficits, and assisting an individual to re-establish or maintain desired habits and routines that support his or her personal identity and sense of well-being. Primary occupational therapy interventions focus on therapeutic activity and include methods to promote sensory integration, cognitive retraining, and task adaptation to achieve, restore, or maintain a particular level of function, especially one that facilitates independent transition into the community and the resumption of an individual's personal and social roles in a particular environment.

Speech-Language Pathology A speech-language pathologist (also known informally as a speech therapist) helps patients with receptive and expressive components of communication, speech production and quality, and language comprehension as well as difficulties in swallowing that may result following disease, injury, or some surgical interventions. Speech-language pathologists employ a variety of methods to increase or augment skills for communication and use alternative communication methods as well as promote the ability to swallow safely.

Rehabilitation Settings

Rehabilitation describes the practice of professionals to address a range of patient needs and is not limited to any particular setting or organizational structure. Rehabilitation services can be accessed through hospitals, inpatient rehabilitation hospitals, outpatient hospital departments and rehabilitation

facilities, private practices, home health agencies, skilled nursing facilities, and nursing homes. Each of these settings is organized to address a certain range of problems, based on the person's current functional status and ultimate prognosis for improvement, concomitant medical issues, tolerance to participation at varying intensities of treatment, the likely duration of the services, and the necessity for a particular efficiency in coordinating multiple services. Some individuals receive rehabilitation services along a continuum, beginning with admission to an inpatient hospital and then being transferred to other inpatient facilities such as an inpatient rehabilitation hospital or skilled nursing facility. Some of these individuals may complete their rehabilitation programs as outpatients. Other individuals will initiate their rehabilitation on an outpatient basis, perhaps with just a single healthcare professional, without any inpatient admission. A person's own preferences and social situation (e.g., safety issues, caregiver availability, the need for 24-h assistance) also influence decisions regarding setting. Each of these settings has its own rules for both admission and payment that will also affect where, how, and by whom services are provided.

Rehabilitation Outcomes

In general, the literature supports the efficacy of rehabilitation interventions to produce changes in impairments and functional limitations. However, what is far less clear is the appropriate dosage of these interventions and the duration of services to ensure that the most appropriate services are provided to patients to ensure optimal functional recovery without unduly wasting resources. Similarly, the impact of setting on outcome and cost has not been fully addressed. The impact of rehabilitation on long-term disability among older individuals is not as well established in the literature, although the available evidence suggests that rehabilitation, especially when coupled with primary and secondary prevention, mitigates the magnitude of disability associated with aging.

See also: Disability, Functional Status and Activities of Daily Living; Human Factors Engineering and Ergonomics; Speech and Communication (speech styles).

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Politics of Aging

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Glossary

Economic Globalization – The increasing integration of economies around the world, particularly through trade and financial flows, as well as the movement of people and knowledge across international borders.

Electoral Politics – Voting, party affiliation, organized political action, and holding public office.

Politics of Aging – How structured economic interest groups interact in ways that have intended or unintended consequences for resource allocation in relation to the age structure.

Introduction

There are many ways to think about the term politics. First, to many people, politics may mean electoral politics, which includes voting, party affiliation, organized political action, and holding public office. Second, at times individuals collaborate to further perceived or real collective interests through the political process. In this sense, the politics of aging may describe social movements that have coalesced over time, particularly those advocating for the creation and expansion of programs benefiting the aged. Third, politics also refers to other processes through which various actors, primarily economic actors such as corporations and business organizations, act in a political field with governments and voluntary and non-governmental organizations to advance their economic interests and influence public policy and practice. These processes are understood through the political economy perspective (*see* Theories of Aging: Social).

In this context, the politics of aging deals with how structured economic interest groups interact in ways that have intended or unintended consequences for resource allocation in relation to the age structure. The political economy perspective on aging provides an ideal framework for this discussion. This approach can be employed at several levels (national, state and local, international) to bridge electoral politics, social movement politics, and the state–interest group processes shaping public policy that include the role of private actors such as investment companies and health insurers. The bulk of this article is organized by sequentially examining the politics of aging from these three approaches, which in fact are linked. The focus is on these three types of social process as they refer to public policy. Public policy establishes and sets the parameters for age-based programs (such as Social Security and Medicare) that specifically target older persons; but also age-related programs such as Medicaid, as well as education, housing, and transportation programs, that may have differential consequences for different age groups, even though age is not a criterion for eligibility.

The politics of aging are socially constructed. That is, the issues faced by the elderly are created by political actors with their own objectives. It is important to understand not only the policies that affect the aged, but also the people and organizations who set the aging policy agenda by framing what shall be considered an issue, a problem, or even a crisis, requiring policy attention. The location of these agenda setters is continuously evolving. Some decisions that impact older persons (Social Security and Medicare, for example) are made at the national level. Others, such as decisions concerning the use of Medicaid funding for long-term care, are made by state and local officials within parameters set by the federal government. But all decisions occur today within a global context in which the United States is but one player. The lives of elders across the world are inextricably linked, because their social and economic contexts are linked through globalization.

This article focuses on the United States but will also attend to policy developments in other countries that are global or international in scope (for example, age-related policy developments by the United Nations (UN), the World Health Organization, and the World Bank). Many developments relevant to aging politics occur in spheres not typically considered by gerontologists, because the political, social, and economic consequences for the aged are secondary or unintended consequences. The article addresses such issues and suggests that they should be considered when social gerontologists examine the politics of aging. Thus, this article views the politics of aging as multifaceted and multilevel in scope.

Electoral Politics

Throughout the developed world, the growing numbers of older people have been a stimulus to age-related politics. The shape of age-related politics varies considerably by the nature of the polity, for example, whether the country has a one-, two-, or multiparty system, whether a federal system (in which national and subnational governments have spheres of influence) exists, whether the system is parliamentary or presidential, and so forth. In the United States, Republican George W. Bush was elected to a second term as President in 2004, with a plurality of 3 million votes over his challenger, Democratic Senator John Kerry. However, as in 2000, President Bush's margin of victory in the electoral college was thin (286–252) and the election was decided by a single state, with a narrow Bush victory in Ohio deciding the contest. In the aftermath of another closely contested election, political pundits made note of an apparent blue state/red state divide in the electorate. In reality, distinctions between Kerry and Bush voters were more subtle. Senator Kerry garnered much of his support in big cities, while President Bush fared extremely well in the suburbs and rural areas. The President also built upon his conservative base from 2000 with increased support from Latino, Jewish, and Catholic voters, as well as from women.

Older voters have long been viewed as a key battleground in presidential politics. This is largely due to the fact that, beginning in 1976, Americans aged

65 and older have turned out to vote at a rate higher than any other age group. However, the idea that seniors play a decisive role in electing the president deserves closer scrutiny. As Robert Binstock has observed, older Americans had voted in previous elections for different presidential candidates in roughly the same proportion as the general population. In the 2004 election, this pattern was once again in evidence, as the two major candidates received almost the same percentage of votes among voters age 65 and older (52% for Bush; 47% for Kerry) as they did among the overall electorate (51% for Bush; 48% for Kerry). Among all age groups, President Bush fared best among voters age 60–64, with 57% of the vote among this cohort. By contrast, Senator Kerry fared best among the youngest category (age 18–29), with a nine point advantage.

The indication that Senator Kerry failed to garner greater support among older voters may appear surprising, given the unpopularity among seniors of the Medicare prescription drug bill and of Bush's Social Security plan (discussed later). It would seem that seniors supporting the Bush–Cheney ticket had voted against their own self-interests. Nevertheless, as Binstock and others have observed, the self-interests of older people vary, and seniors as a group have rarely voted solely on the basis of programs for the elderly. Postelection polling indicated that Kerry voters across all age groups identified the economy or the war in Iraq as the most important issue in the election, while Bush voters reported that the candidates' moral values mattered the most. However, in closely contested states such as Ohio and Florida, President Bush's advantage over Senator Kerry on the issues of terrorism and national security was considered the most decisive factor.

The 2004 election provided an opportunity to reexamine voting patterns by age and perhaps to reassess assumptions made about age-related patterns in voting behavior. Previous elections revealed little variation among age groups in voting preference, but significant differences in terms of participation. From 1966 to 1996, voting rates among older persons increased while turnout among younger voters declined. However, different age patterns emerged in the 2004 election: significant age-related differences in voting preference, but less variation in terms of participation. Exit poll data revealed an 8% increase in turnout among voters under age 30 from the 2000 election; the ranks of younger voters grew as much as those of older voters in this election. The key question in age-related voting behavior is no longer simply Why are older persons voting in higher numbers? but also Why has voter turnout increased among the young?

To understand the factors that guide electoral decisions among different age groups, we inevitably ask whether age, period, or cohort effects are operating. An age effect would be suggested if people were found to become more conservative as they grew older. A cohort effect would be evidenced if the values of people who are older adults today have been consistent over their lifetimes. A period effect may exist if persons of all ages were inclined toward a specific set of values during one historical era, but a different one in the next.

There are reasons to question whether any of these three types of effects was decisive in the 2004 US election. As previously noted, older citizens rarely vote on the basis of apparent age-related interests. Perhaps other, indirect age-related effects are operative. For example, the elderly have had a lifetime to form political philosophies and allegiances; concerns about their children and grandchildren may lead their attention away from later-life issues; and their age may simply not be a salient aspect of their identity. In the 2004 election, the presence of a cohort effect is undermined by the fact that the age group 65 and older, a generation previously identified as alienated from politics, had the highest voter turnout. Finally, in this election there was little evidence for a period effect cutting across all age groups in respect to issues such as same-sex marriage. With a divided and volatile electorate, it may be years before we can discern what drives voting behavior of Americans.

It is not possible in this space to adequately represent the variations in electoral politics of aging around the world. Suffice it to say that a different dynamic exists when more than two political parties are present. Unlike the United States, where the choices of older persons are limited to two major parties that may or may not prioritize their interests, older persons in many other democracies can turn to a larger number of viable parties more attuned to their interests. For example, in Italy, which has many viable political parties, older voters can communicate their desire to preserve the welfare state status quo through their support of parties opposed to pension reform. As Alan Walker notes, smaller pensioners rights parties have also formed in Germany, Denmark, and the Netherlands.

Social Movements

Another way in which age can be relevant to the political process is through the development of age-based interest groups and the mobilization of these groups in social movements. Prior to the twentieth century, there was little notion of group consciousness among seniors, largely because the number of

older people had not yet reached critical mass. However, with increasing life expectancy came the rise of the older population, the creation of public programs serving the aged, and a growing awareness of the needs of older persons, leading to broad-based movements for aging policy.

In the United States, grass roots movements (for example, Townsend clubs) organized around individual reformers during the 1920s to agitate for the creation of an old age pension (which already existed in several European countries), and years of pressure culminated in the Social Security Act of 1935. While most accounts of its passage attribute the legislation to a policy elite within the administration of President Franklin Roosevelt, Social Security was nonetheless seen as the first triumph of 'gray power.' Individual reformers eventually gave way to organized political interest groups. By 1990, as Christine Day observed, there were more than 1000 aging-based interest groups in the United States functioning at local, state, and national levels and representing a broad ideological and political spectrum. Day also noted that these interest groups vary widely in size and the ways in which they find their support, with many lobbying groups receiving support from private foundations, government agencies, and philanthropists.

The largest aging interest group is AARP (formerly the American Association of Retired Persons), with more than 30 million members (many of whom are attracted by AARP benefits, such as travel discounts). Other more policy-driven organizations include the National Council of Senior Citizens (NCSC), the National Committee to Preserve Social Security and Medicare, and the Gray Panthers. The effectiveness of this 'gray lobby' is the subject of much debate. For example, despite its large membership and public policy division, AARP has historically achieved limited success in expanding public benefits for the aged. One example is the Medicare Catastrophic Coverage Act (MCCA), passed by Congress in 1988 with AARP's support. The MCCA was designed to increase coverage for high-cost care, but it was quickly repealed due to the protest of upper-income elders, who were to be assessed a surtax to finance these new benefits. Recent achievements of the gray lobby have largely been in sustaining existing public programs for the aged in the face of efforts to dismantle them. In 2005 AARP had a major impact in its efforts to derail President Bush's proposal to privatize Social Security.

Social movements centered on aging have been a largely American phenomenon, and aging interest groups have been slow to develop in other countries. However, recent years have seen an upsurge of political activity by organized aging groups in other countries, with gray parties winning seats in the national legislatures of the Netherlands and Czech Republic, and associations forming to prevent cuts in senior services, such as the Gray Panthers in Germany. In contrast to the United States, few other industrialized countries have a single, large mass-membership organization such as AARP that advocates on behalf of the elderly. Canada, for example, does not have a comparable large advocacy-oriented interest group, and an attempt to establish one (One Voice for Seniors) failed. In Italy, pensioners' unions are recognized as the driving force behind that country's elderly oriented welfare state, while in other countries, the most visible aging interest groups represent specific sections of the older population (such as retired civil servants in Great Britain).

Finally, internationally oriented groups pursue advocacy and agenda-setting activities for aging policy on behalf of the aged. One example is HelpAge International, a global NGO with affiliates in 48 countries, which focuses on poverty issues of the aged in the global context. HelpAge International has also influenced European institutions to include intergenerational approaches in their development policies, and it provides direct policy advice to governments in many developing countries. Working with partner organizations, it has advocated for relief of older caregivers of persons with HIV/AIDS in Africa and Asia. Another example is the International Federation on Aging (IFA), which promotes social engagement of and on behalf of older people throughout the world through conferences and publications. IFA can be viewed as an agenda-setting organization, advocating for the well-being of older people through an informal network of Ministers of Aging around the world. The IFA Declaration of Rights and Responsibilities of Older Persons was a foundation for the UN Principles for Older Persons, adopted by the UN General Assembly in 1991.

Political Economy

As scholars such as Carroll Estes have described, the political economy perspective is predicated on the view that old age is socially constructed and that the power struggles between actors such as international capital, the state, and the medical–industrial complex are the forces that shape social policy. This perspective, which emphasizes the broad implications of structural forces and processes such as electoral politics and social movements, provides the framework for discussion of age politics in the income security and health-care policy domains.

Income Security

Across the globe, public pensions have been high on the policy agenda and subject to the politics of age. While some developing countries are struggling to establish state pension plans to accommodate their rapidly aging populations, several developed countries have contemplated, if not implemented, changes to pension systems designed to lower the costs to the state of pension provision and, in many cases, to promote higher employment in the later years or at least counter a trend to early retirement. Almost all of the countries in the developed world have gone through at least one major reform to their old age security systems. The path of this reform largely depends on the nature of the pension program already in place.

In the United States, Social Security reform has risen to a major place in the policy agenda of the Bush administration. The President has proposed a major revamping of the program's current pay-as-you-go funding mechanism, under which benefits for retirees are financed through the earnings of the employed. His proposal would allow workers to divert part of their payroll taxes currently earmarked for the Social Security trust fund into private investment accounts, shifting responsibility for income security in old age from the state to the individual. However, privatizing Social Security is not a new idea. Economists at the University of Chicago and the Cato Institute have proposed private investment as the solution to an eventual Social Security shortfall since the early 1970s. In 1995, Senators John Danforth (R, MO) and Bob Kerrey (D, NE) advanced their own partial privatization proposal, and the idea has been on the policy table ever since. Nor is the United States the first country to consider privatizing a public pension program. Chile, with a push from the World Bank, adopted a fully privatized income security system in 1981, and several other countries in the global south have discussed similar changes.

President Bush's plan to reform Social Security shares with these earlier efforts the conviction that the responsibility for financial security in old age rests with the individual, not with the government. The President has described personal retirement accounts as the centerpiece of an ownership society and has promised that private accounts would provide beneficiaries a higher rate of return in retirement. He has also attempted to garner support for privatization by defining the status quo as a crisis, warning that the Social Security trust fund would run out of money as Baby Boomers began to retire and that the system would be bankrupt by 2041 unless action was taken today. However, the public response to privatization has been generally unfavorable. AARP stated its opposition to carving private accounts out of existing Social Security revenue. Other critics noted that these private accounts would actually harm the long-term solvency of Social Security by diverting money from its trust fund. Instead of privatizing the program, it has been argued, minor corrections to the program such as raising the cap on earnings subject to the payroll tax can ensure the long-term stability of the Social Security program.

Whether public or private provision is more efficient is an empirical question. However, the arguments made in the pension debate tend to be based on ideological grounds. When President Bush described Social Security as a system in crisis, he drew on a rhetoric that had been advanced for many years in the debate over the concept of generational equity, which refers to the principle that different cohorts should be treated equally in terms of resource allocation and should have similar opportunities. Organizations such as Americans for Generational Equity (AGE) and the Concord Coalition have argued that generations currently old have received more government resource allocation (such as for pensions and health care) than the younger generations will receive over their lifetimes, and that older generations have contributed less to the government through taxes and other contributions than will younger cohorts. These groups have recommended reduced transfers to the aged as the solution to generational inequity.

The argument that there is generational inequity has been used as an attack on public pensions and a justification for privatization and the individualization of risk. However, this general form of argument has been severely criticized. For example, the generational equity perspective downplays the diversity in economic conditions and political behavior among the elderly. Further, there is little evidence that current policies toward the elderly adversely affect younger adults. Finally, conclusions that old age policies are unsustainable based on dependency ratios fail to take into account recent demographic trends, such as the many older adults who remain in the labor force. Despite these criticisms, the generational equity perspective remains a concern for the politics of aging. This rhetoric not only persists, but also informs the agenda setting for politics against the welfare state and toward individualism.

Public pension programs in other industrialized nations suggest that there are alternatives to the public pension framework in the United States. Other countries with earnings-related pension programs have successfully avoided the threat of shortfalls. Canada's two-tier program, comprising

work-related and non-work-related income, is one example of a public pension system that is not in crisis. On the other hand, several nations that have more recently created old age pensions (for example, Australia, Ireland, the Netherlands, and New Zealand) have opted for universal or quasi-universal capitalized pension schemes. Public pension reform is on the political agenda of almost all the highly developed countries. However, privatization is not the only option available to fix a national income security system. Japan has scheduled future increases to payroll taxes, while Austria and Finland have adjusted the systems by which earnings are calculated. Incremental measures such as these may prove more feasible than the current Bush proposal to reform Social Security.

The politics of social insurance cannot be separated from the issue of private pensions. Every industrialized country has developed its own mix of public and private provision of income support in the later years, with a growing number of countries moving away from the traditional safety net of public programs and relying more heavily on the private sector. Over the past quarter-century, the predominant structure of employer pension plans (which cover half of private full-time workers in the United States) has changed. In 1980, 83% of private pensions in this country were defined benefit plans, in which the employee receives a guaranteed retirement benefit, usually provided on a monthly basis. The majority of private pensions today are defined contribution plans, in which employees invest a portion of their earnings into their choice of employer-sponsored investment packages. In this way, the responsibility of providing a retirement nest egg for employees has been shifted from the corporation to the individual.

Defined contribution plans were supported by institutions such as AGE and the Concord Coalition that embraced the implicit emphasis on individual responsibility, as well as the idea that the market would eventually solve the problem of a rising ratio of retirees to workers. During the 1990s, a healthy stock market supported this principle. However, the pension system in the United States is currently in disarray. Corporate fraud led to the failure of several defined contribution plans in the early 2000s, including those of Enron, Tyco, and MCI WorldCom. Employee investors in these companies' programs lost their entire pensions, with no hope of reimbursement. The picture for defined benefit plans is also bleak. United Airlines and many other companies have recently terminated their defined benefits pension programs and are unable to meet their obligations to retirees. The Pension Benefit Guaranty Corporation, the federal agency that guarantees defined benefit plans, is now responsible for the pensions of over 130 000 United employees and many other employees and retirees.

In short, the private pension systems in the United States appear vulnerable as American corporations seek to cut costs in order to remain competitive in the face of increasing global competition. This trend poses potentially dire consequences for millions of individuals as they approach old age, as the pension crisis threatens to dismantle one of the traditional sources of retirement income in the United States. The turmoil surrounding private pensions has also had political fallout. Reports of corporate malfeasance have eroded public support for efforts of conservative policymakers to shift the responsibility of income replacement from the government to the individual, as they have reminded Americans of the risks inherent to personal investment. In particular, the private pension crisis has helped to undermine the President's efforts to privatize Social Security; this is one indication that the United States is not yet ready to abandon the welfare state, and embrace the financial market, in order to provide income security for the aged.

The fate of private pension plans in other developed countries is similarly dependent on the vagaries of the global marketplace. This is particularly a concern in countries in which income security in old age is closely tied to private investment (for example, Australia and Ireland). In nations such as these, where an established earnings-based public pension system (as in the United States, Canada, and much of continental Europe) is lacking, the nest egg for aging citizens may consist almost entirely of private pension benefits, leaving these individuals particularly vulnerable in the event of an economic downturn. It may well turn out that a balance between public and private pension benefits is necessary for aging individuals in a global economy.

Health Care

Pensions and health care constitute two major areas of expenditure for modern welfare states. While many national medical care insurance systems are experiencing fiscal strain, the health-care insurance system for older adults in the United States is also reputed to be in financial crisis. Medicare's financial problems are believed to exceed those of Social Security; according to two independent trustees, the Medicare trust fund will be exhausted by 2020. Per capita health-care costs have continued to grow rapidly due to the development of new technology and to the increased use and costliness of medical care.

The cost of the new Medicare prescription drug program, created under the Medicare Modernization Act (MMA) of 2003, is projected to grow to $100 billion per year by 2014, far beyond initial estimates. The rising costs of acute care services under Medicare Parts A and B, coupled with the larger-than-expected price tag of the prescription drug program, fuel fears over the long-term solvency of Medicare, which are only heightened by the anticipated needs of the 70 million Americans who will reach old age by 2030.

However, from the political economy perspective, the concern over the future ability of Medicare to provide affordable health care to older Americans is another socially constructed problem. The Medicare program is not the source of this impending crisis; health-care costs for older Americans have risen because all health care in the United States has become more expensive. National medical expenditures have grown more than 350% since 1980; annual health-care costs in the United States are projected to reach $2.18 trillion by 2008 and to continue to grow at a rate faster than that of the overall economy. Medical costs per capita have actually grown more slowly among older Americans than among the general population, in large part due to the Medicare cost containment strategies of the 1980s and 1990s. In short, as Jon Oberlander warns, the crisis in health care is one facing all Americans, and it is due to the lack of centralized budgetary controls, higher prices, higher administrative costs, and, in some cases, greater use of high-cost medical technology in the American health-care system.

Thus, the challenges facing Medicare must be understood in the larger context of how health care is socially constructed in this country, specifically, why the United States is alone in the developed world in not providing universal national health insurance covering people of all ages. This nation's political institutions are important contributing factors. Contrary to the centralized governments of Great Britain and other European nations, powers are divided in the United States between three separate branches of government (executive, legislative, and judicial). Also, in the federal system of the United States, administrative duties are shared by national and state governments, further increasing the number of veto points at which health-care reform can be blocked. Further, a two-party system characterizes American politics, reducing the potential for the policy innovations that have emerged from reform-minded parties in Canada and elsewhere. The absence of a party representing the labor movement in the United States is a particular hindrance to expansion of the welfare state. Finally, the American political ideology, which tends to emphasize individualism, has limited the growth of public programs based on the principle of collective solidarity.

These factors have created obstacles to national health insurance, which have been exploited by its opponents. In the United States, different stakeholders have derailed previous attempts at major health-care reform. In the early twentieth century, physicians, represented by the American Medical Association (AMA), lobbied against government-financed health care, which they regarded as a potential intrusion to the doctor–patient relationship. In recent decades, the health insurance industry, viewing national health care as a threat to their control of the health-care market, has moved to the forefront. Over time, these different coalitions have employed similar tactics. First, they have defined a possible government takeover of health care (and not the lack of affordable health care for millions of Americans) as the crisis in this policy area. Second, opponents of health-care reform have used the fragmented nature of American politics described previously to full advantage, successfully lobbying Congress to block six different presidential proposals for universal coverage, most recently President Clinton's in 1994. Consequently, health care in the United States has been largely ceded to the private sector.

As Jacob Hacker has chronicled, national health insurance has long been a fixture in other industrialized nations, beginning with Germany in 1883. In 1948, Great Britain became the first Western democracy to provide free and universal medical care; in Canada, universal health-care coverage (through provincial governments) was initiated in 1971. Programs such as these are alike in their provision of health care that is more extensive and less expensive than that which is available in the United States. However, each country's path to universal coverage has been unique. National health insurance has arisen not as the result of widespread demand, but through the efforts of policy elites in these respective nations, acting in different historical periods in response to specific health conditions, interest group configurations, governmental constraints, and political windows of opportunity. Further, the United States is an exception in the developed world in restricting universal health-care coverage to those aged 65 and older; the politics of age are less salient in the health-care politics of other countries.

Long-term care (LTC) is a related health-care issue that is particularly salient for the aged and disabled. The system of long-term care in the United States has developed in piecemeal fashion. Medicare, based on the private health insurance plans of its time, contained no provision for long-term care. However,

Medicaid, which allows states to enroll persons who became medically needy due to high medical costs, has become the largest purchaser of long-term services in the United States. An institutional bias has long existed in Medicaid's payment of long-term care; nursing homes are the most prevalent destinations for these services, and the nursing home industry has lobbied successfully at the national and state levels to preserve this dominant position. While several states have experimented with using Medicaid funds to support alternatives to nursing home care, such as in-home nursing assistance and community-based respite care, these programs are vulnerable to Medicaid cuts recently proposed by the Bush administration. At the national level, the focus on LTC is recent and relatively minor compared with the attention paid to medical care.

In contrast to physician and hospital care, provision of LTC in the United States is fairly typical of rich democracies. While some countries, such as Germany and Japan, have created some form of social insurance for LTC, and Canada is likely to implement such a system, most have relied on an ad hoc mixture of national and subnational funding and administration, many (like the United States and some provinces of Canada) with a means test and requirement to spend down assets. In other words, LTC throughout the developed world has evolved in piecemeal fashion, separate from national health-care plans. Like the United States, most countries are approaching the demand for LTC services in the future without a comprehensive plan in place.

In summary, any understanding of the politics underlying either income security or health-care policies must recognize that the public–private distinction is fuzzy at best. As Hacker has illustrated, national policies have sustained the growth of private insurance markets, either directly through tax subsidization or indirectly through public coverage of high-cost populations. At the same time, however, private insurers have constrained government efforts to expand public insurance or regulation.

Globalization

As is evident from this discussion of current aging policy issues, gerontology has become aware of and concerned about globalization. More importantly for the politics of aging, major actors concerned with globalization have become concerned with aging. These developments move gerontology to a new, international focus and place local and national issues in the context of global social and economic forces. The social and economic processes of globalization generate tremendous controversy and conflict, with some praising its benefits and others decrying what they see as the exploitation of underdeveloped countries by first-world countries. Walker (2005:817) maintains that "it is not globalization per se that is problematic but its dominant neo-liberal economic form."

In 2000, the International Monetary Fund (IMF) defined economic globalization as the increasing integration of economies around the world, particularly through trade and financial flows. Economic globalization also refers to the movement of people and knowledge across international borders. The term global aging depicts the world as a holistic system, addressing international demographic changes in areas such as health and family support. However, its focus is mostly in the economic realm, specifically, the impact of global aging on the economies of countries at various levels of economic development, and whether the global economic system can afford to support the needs of a growing older population. Because population aging varies across nations, it is possible that differential aging will have an impact on market economies, affecting the social situation of older people differently in have and have-not countries, as well as special groups of the aged such as migrant workers and immigrants.

Concerns about global aging take on an even more dramatic tone when it is asserted that economic conditions affect international stability. Two initiatives in particular illuminate the forces driving the international politics of aging. The first is the release of a policy paper by the US Central Intelligence Agency under the title *Long-term Global Demographic Trends: Reshaping the Geopolitical Landscape*. The report asserts that global demographic trends will have far-reaching economic, military, and political consequences. By 2050, the size of the age 65+ population will have tripled, to about 1.5 billion people, or 16% of the total. Many developing countries (the report specifically names Pakistan, Afghanistan, Saudi Arabia, Yemen, and Iraq) will see significant youth bulges. Countries such as these face great economic challenges creating productive work for large youth and young adult populations. However, countries that are currently the economic engines of the world face a far different problem, the report alleges, because of population aging. While the young countries may see great unrest due to continuing poverty and the challenge of meeting the needs of rapid population growth, the old countries, struggling economically because of their aging population, may be less able to deal with geopolitical flashpoints.

The second significant initiative is the Global Aging Initiative program undertaken in 1997 by the Center for Strategic and International Studies (CSIS) in Washington, DC, and backed by high-level

government leaders, top executives of major global-reach corporations (including international insurance and venture capital companies), academics, and think-tank representatives. According to their report, Japan, Western Europe, and the United States will undergo unprecedented demographic transitions over the next 30 years characterized by a "dangerous combination" of rising elderly populations and negative labor force growth. CSIS asserts that the fact that this transformation is limited to the world's leading economies has far-reaching consequences for global security and economic stabilization. As with the CIA report, the CSIS Global Aging Initiative is concerned not only with economic issues, but also global security issues, communicating a vision of apocalyptic demography.

These two examples illustrate the point that the politics of aging, in a global context, involves major parties and interest groups, including governments and corporations seeking to set the agenda through which national and international policies will be put in place. Powerful voices from sectors other than the field of gerontology argue that there is a crisis of global aging and make a number of proposals to ameliorate the problem. The general tone of such recommendations parallels those of AGE and the Concord Coalition that had been framed at the national level in the United States, for a shift of responsibility for Social Security and health care from the state to the individual and for steps to be taken to retain people in the workforce to more advanced ages, as a means to both meet labor force needs and reduce fiscal strains on both the pension and health-care systems. Many academics and some interest group organizations, such as AARP, oppose the crisis rhetoric, as well as the focus on the economic aspects of globalization (as opposed to its social costs). As Walker argues, globalization makes increasing inequality inevitable, particularly by raising questions about the sustainability of pension and social protection systems that mainly benefit the older population. The use of crisis rhetoric by these organizations serves to legitimize neo-liberal attacks on the welfare state, which as we have noted, is very relevant to the lives and life chances of older people.

Finally, there has been a decided shift of focus toward developing and transitional countries, as international organizations have begun to pay more attention to the social consequences of globalization for older people. These include the efforts of the UN, which issued the Vienna International Plan of Action on Ageing in 1982 and the Madrid International Plan of Action in Ageing in 2002, adopted a resolution containing the United Nations Principles for Older Persons in 1991, and declared an International Year of Older Persons in 1999. In addition, the World Health Organization (WHO), a constituent agency of the UN, issues similar statements in the global aging and health area. The UN and the WHO have very few resources to advance their own agenda, but statements these agencies issue become material that can be used to legitimate policy positions of UN member states.

Conclusion

This article began by noting the complexity of the field of politics of aging and that its scope would be broad, going beyond electoral politics to include social movement politics and to frame this discussion in a political economy perspective that recognizes the importance of actors such as political parties, interest groups, corporations, and non-government organizations. Political decisions at many levels affect the aged, even if the decisions are not made with the aging in mind, and instead concern issues such as international economic competitiveness. It is likely that certain actors have more resources to bring to the process of agenda setting, and are thus likely to strongly influence the policies that affect the well-being of older people, whether these are aging policies, economic policies, health policies, or other kinds of policies. In addition to familiar domestic players such as AARP and the Concord Coalition, international organizations are also helping to shape the politics of aging at home and abroad. Our major goal has been to broaden the scope of interest in the politics of aging. Another major goal has been to stress that the so-called problems of aging are socially constructed. In this sense, electoral politics, social movements, and the political economy of aging are interrelated.

Acknowledgments

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See also: Globalization and Aging; Health Care and Services; Long Term Care; Medicare and Medicaid and Economic Policy of Health Care; Organizations On Aging; Social Security; Theories of Aging: Social.

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Premature Aging

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Glossary

Progeroid Syndromes – Premature aging syndromes.

Introduction

Professor Mitchell Turker's excellent article on this subject in the first edition of the *Encyclopedia of Gerontology* covered fundamental mechanisms of aging as well as syndromes that were thought to lead to premature aging. There has since been substantial progress in both areas, precluding any systematic coverage of both topics. Moreover, despite numerous publications, there is still no consensus on the number and types of fundamental mechanisms of aging. Even the venerable free radical theory or oxidative damage theory has been recently challenged (but not falsified) by an analysis of mice that are prone to undergo mutations in their mitochondria. Surprisingly, there is also a paucity of information on the detailed phenotypes of aging in model organisms such as round worms, fruit flies, and even laboratory mice. The term progeroid syndromes, therefore, is used here in order to emphasize the uncertainty in deciding the degree to which premature aging syndromes in fact match mechanisms and phenotypes of aging as they usually unfold. Given the paucity of information on the phenotypes of aging in model organisms, most of this article deals with humans, for which there is indeed a great deal of information on how aging changes structure and function. But it also gives two examples of progeroid syndromes in mice, as the genetic analysis of mice is now well developed, providing the potential to elucidate basic mechanisms of mammalian aging. The genetic basis of progeroid syndromes is emphasized because genetics has great power to reveal primary mechanisms. It is important to keep in mind that discoveries of variations in genes that appear to accelerate aging raise the possibility that there also exist variants that contribute to enhanced structure and function during the life course. The article also considers, however, some examples of environmental agents that have the potential to accelerate features of aging.

Differentiating Premature Onsets of Aging and Accelerated Rates of Aging

Very few publications attempt to differentiate conditions in which aging begins at a prematurely early

age and conditions in which aging begins at a usual age, but proceeds at an accelerated pace. It is also apparent that both phenomena may occur as a result of genetic mutations or environmental factors. A formal mathematical analysis of rates of change in age-specific mortality rates is helpful in differentiating these two types of premature aging.

Gene Variants Associated with Progeroid Syndromes

Segmental Progeroid Syndromes

There are no known agents, environmental or genetic, either in humans or in mice, that move forward in time all aspects of aging. The term segmental progeroid syndromes was therefore introduced to emphasize that only a subset of features of aging are affected in any given condition. There are a great many such genetic syndromes in humans. They appear to reproduce, with variable fidelities, aging as it usually occurs. A subset of the most informative examples, those for which a responsible genetic mutation has been discovered, is reviewed here. A number of such reports have appeared since the publication of the first edition of this encyclopedia. With the exception of older literature on the effects of ionizing radiation, there has been much less research on the potential roles of environmental agents capable of accelerating features of aging. Perhaps the best candidate of an environmental segmental gerontogen is cigarette smoking, which not only causes certain forms of cancer in mid-life, but also has progeroid effects in the reproductive, cardiovascular, pulmonary, musculoskeletal, and integumentary systems.

Werner Syndrome Werner syndrome (WS) (**Figure 1**) is the prototypical segmental progeroid syndrome of humans. It is sometimes referred to as progeria of the adult in order to differentiate it from progeria of childhood (see following section). WS results from a deficiency of a member of a family of proteins (helicases) that function to unwind double-stranded DNA. In order to do business with DNA, e.g., replication, recombination, repair, and transcription, the duplex DNA has to be unwinded so that specialized protein machinery can gain access. The Werner protein (WRN) is unusual in that it also functions as an exonuclease (i.e., it can digest base pairs from the ends of DNA). Precisely how WRN works is a subject of intense research, but a consensus is emerging that it is required for DNA transactions with unusual substrates, such as those that are found at the ends of chromosomes (telomeres) or as intermediates during the recombination of the genetic material (Holliday junctions). At the cellular level, elevated frequencies of both large-scale somatic chromosomal mutations and point mutations are observed, as are striking limitations of the replicative potentials of somatic cells.

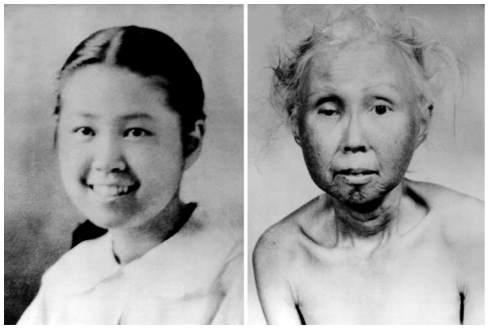

Figure 1 Photographs of a patient with Werner syndrome. (A) Age 15 years. (B) Age 48 years. See Epstein CJ *et al.* (1966) *Medicine* 45: 177–221 for information on this patient (Case 1-M8a) and her pedigree. The syndrome is caused by a double dose of a mutation in the *WRN* gene, the product of which unwinds double-stranded DNA. Reproduced with permission from the University of Washington.

WS patients exhibit a striking array of progeroid features, typically beginning at the time of puberty, when they do not enjoy the usual adolescent growth spurt. This is followed by premature thinning and loss of hair, loss of subcutaneous fat, bilateral ocular cataracts, gonadal atrophy, osteoporosis, type 2 diabetes mellitus (although not in all patients), several forms of arteriosclerosis and, in many patients, cancer. The cancers tend to be sarcomas rather than carcinomas, just the opposite of the situation in normative aging. The distribution of the osteoporosis is also unusual; there is less impact upon the vertebrae than upon the long bones of the limbs. Death usually results from cancer or from a myocardial infarction at a median age of around 47 or 48.

Hutchinson-Gilford Progeria Syndrome Hutchinson-Gilford Progeria syndrome (HGPS) (**Figure 2**) is also known as progeria or progeria of childhood. Unlike WS, which has an autosomal recessive mode of inheritance, it is caused by a dominant mutation of a type known as a gain of function or a dominant negative. The affected gene is known as *Lamin A/C*. It codes for a protein that coats the inner lining of the nuclei of cells. There is evidence that defective forms of the protein result in two broad classes of abnormalities – a mechanical weakness of nuclei, with herniations of nuclear material, and defects in the regulation of gene expression. There is also evidence of accelerated replicative senescence of cultured somatic cells, but this is not as striking as in WS.

Figure 2 Photographs of Rachel, a patient with Hutchinson-Gilford syndrome (progeria). (A) Age 13 months. (B) Age 9 years. The syndrome is caused by a dominant mutation in the *Lamin A/C* gene, the product of which forms part of the inner lining of nuclei. Reproduced with permission, courtesy of The Progeria Research Foundation.

Symptoms appear within the first few years of life. There is marked loss of subcutaneous fat, growth failure, severe abnormalities of cartilage and bone, including osteoporosis, and a severe form of arteriosclerosis. The latter is the usual cause of death, typically at about the age of 13. There is controversy concerning the extent to which this mimics atherosclerosis, the most common form of arteriosclerosis. An unusual aspect is the severe degree of loss of arterial smooth muscle cells. Cataracts and insulin resistance have been occasionally reported, and there is at least one case report of a malignancy (a sarcoma of the chest wall). Many other features of normative aging are not apparent, however. HGPS is extraordinarily rare (about one in four million births). It has been associated with advanced paternal age, consistent with the notion that sperm from older fathers are more likely to harbor mutations, most of which would be expected to have deleterious effects on the fetus.

Cockayne Syndrome Cockayne syndrome (CS) (**Figure 3**) is caused by the inheritance of genes that are thought to be of special importance in the repair of DNA within genes that are active in transcribing their information from DNA to RNA. The clinical syndrome has been associated with at least two such genes, one on chromosome 5 and the other on chromosome 10. Other genes that are important for transcription-coupled repair cause different progeroid syndromes, one of which (a form of xeroderma pigmentosum) is discussed later.

Figure 3 Photographs of a patient with features of both Cockayne syndrome and a form of xeroderma pigmentosum at ages 18 months and 6 years. The syndrome is caused by a deficiency in the repair of the DNA of genes that are active during transcription. Reprinted from J. O. Andressoo and J. H. J. Hoeijmakers (2005) Transcription-coupled repair and premature ageing. *Mutation Research* 577: 179–194, with permission from Elsevier and J. H. J. Hoeijmakers.

Like HGPS, CS causes a major impact upon development. It is therefore difficult to determine the extent to which the complex phenotypic features result from failures in development or postdevelopmental biological aging. There is profound growth failure and severe developmental/degenerative changes in the central and peripheral nervous systems. There is regional loss of subcutaneous fat, a common theme for many progeroid syndromes, contributing to prematurely aged, wizened facies. Other features include

retinal degeneration, optic atrophy, ocular cataracts, corneal opacities, sensorineural hearing loss, hypertension, cardiac arrhythmias, skin atrophy, kyphosis, and proteinuria.

Ataxia-Telangiectasia Ataxia-telangiectasia (AT) is yet another example of a progeroid syndrome caused by a deficiency of a gene product of central importance to the maintenance of genomic stability. Others could also be cited, permitting a generalization of what would seem to be intuitively obvious – namely, that an organism that has lost proficiency in maintaining the structure and function of its DNA will develop a pleiotropic set of signs and symptoms that only get worse during aging. These observations support the hypothesis that increasing genomic stability pays a major role in normative aging.

AT, like CS and WS, exhibits an autosomal recessive mode of inheritance. The mutant gene product, ATM, is an enzyme (a serine kinase) that regulates the response to certain forms of DNA damage, including ionizing radiation. When it is functioning normally, it signals a key molecule (p53) to assist in arresting progression of the cycle until the damage can be repaired. The checkpoint for arresting progress of the cell cycle is just before the beginning of another round of DNA synthesis. If repair is not successful, the pathway signals the cell to undergo apoptosis – a form of cell suicide.

AT patients develop degeneration of the Purkinje cells of the cerebellar cortex, resulting in a debilitating ataxia. Other progeroid features involve hair, skin, and the immune system. The immune deficiency results in an increased susceptibility to infections, particularly pulmonary infections. AT patients are also susceptible to certain forms of cancer, especially to lymphomas and leukemias.

Dyskeratosis Congenita, Autosomal Dominant Form Dyskeratosis congenita (DS) is of special interest to gerontologists because it is caused by a mutation in the gene coding for the RNA component of telomerase, an enzyme that is essential for maintenance of the ends of chromosomes. The absence of telomerase should have particularly significant consequences for stem cells, certain differentiated somatic cells, and the germline, as there are normally high levels of this enzyme activity in such cell types. In the absence of telomerase, repeat units at the ends of chromosomes are lost, leading to chromosomal abnormalities and exit from the cell cycle. The absence of the enzyme in most forms of replicating somatic cells is thought to be the major factor in replicative senescence. DS can be classified as a segmental progeroid syndrome, as patients have scanty hair, dystrophic nails, abnormalities in skin that partially overlap with normative skin aging, osteoporosis, immune deficiency, anemia, somatic cytogenetic abnormalities, and premalignant changes in mucosa. There is likely to be germline maldevelopment and/or atrophy, but this is not well studied. Like a number of progeroid syndromes, there is always concern that the phenotype may be largely due to impacts upon development rather than impacts upon aging. That said, it is of interest that there is evidence of increased rates of loss of telomere repeats in several segmental progeroid syndromes, including WS and HGPS.

Down Syndrome Most forms of Down syndrome (DS) are caused by an extra copy of chromosome 21 (trisomy 21), but it can sometimes be caused by chromosomal lesions that result in an extra copy of a critical portion of chromosome 21. Progeroid features include graying of the hair, ocular cataracts, hearing loss, early ovarian failure, diminished bone density, and certain leukemias. The most striking and relevant feature, however, is the development of all of the neuropathological features of Alzheimer's disease by middle age in essentially 100% of patients. This may be attributable to the extra copy of the gene for the β-amyloid precursor protein. DS is the most common chromosomal abnormality in newborns. Its frequency rises dramatically with advancing maternal age, probably reflecting aging processes within oocytes.

Mitochondrial Mutator Mice Two independent research groups have genetically engineered mice that have lost the ability to proofread errors in the enzyme (DNA polymerase gamma) that replicates mitochondrial DNA (**Figure 4**). This model is of special interest because the progeroid features have no obvious association with elevated levels of free radicals or of oxidative damage to macromolecules. The results thus pose a challenge to the free radical theory of aging. It may be, however, that the mitochondrial dysfunction that occurs during normative aging does indeed involve oxidative stress, as there are a number of lines of evidence supporting that proposition. The genetically engineered lesion in this animal may represent another pathway toward mitochondrial dysfunction. The progeroid features include a dramatically shortened life span despite apparently normal development, graying and loss of hair, loss of bone mass, kyphosis, loss of muscle mass (sarcopenia), testicular atrophy, loss of intestinal crypts, anemia, and hearing loss. It is of interest that this collection of phenotypes is more characteristic of human aging than of normative mouse aging. The same statement can be made about other mouse

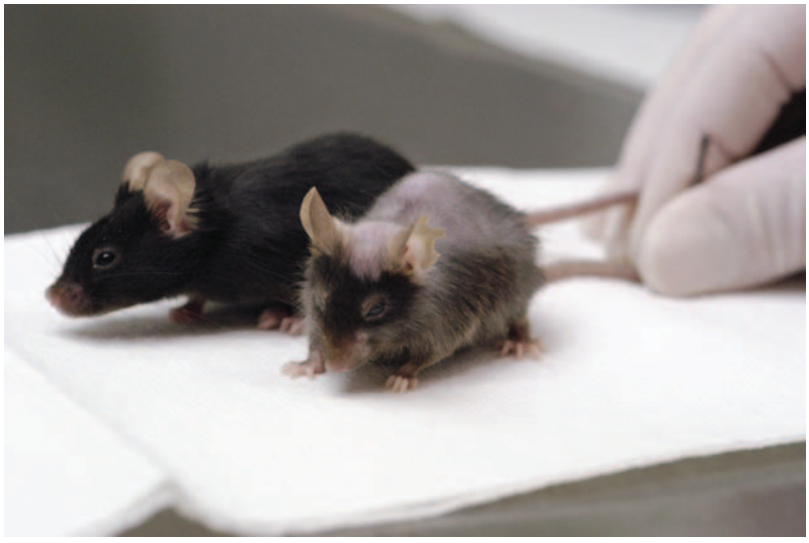

Figure 4 A normal 13-month-old male mouse (left) and a 13-month-old male mouse with a mutation in a gene (DNA polymerase gamma) that replicates mitochondrial DNA (right); the part of the gene that has been mutated is responsible for proofreading the replicated DNA. Reprinted with permission from T. A. Prolla (photograph by Jeff Miller, University of Wisconsin-Madison).

models of premature aging, including the following example.

The Klotho Mouse The term Klotho is derived from the name of the Greek goddess who 'spins the thread of life.' This mutant mouse model of premature human aging was discovered by accident – a gene that was introduced into the genome of the mouse happened to land in and therefore mutate the gene now known as Klotho. This model is of special interest because subsequent research has shown that overexpression of the Klotho gene leads to increased life span, a much more valuable phenotype from the point of view of our understanding of fundamental mechanisms of aging. Klotho appears to code for an enzyme with features of a β-glucuronidase. Although it is expressed mainly in the distal convoluted tubules of the kidneys and in the choroid plexus of the brain, a portion of the gene product circulates and acts as a hormone. It may also act as a paracrine hormone, affecting nearby cells, especially in the kidney. The major impact of the gene is thought to be on the metabolism of calcium and phosphate. Precise details of mechanisms are currently being pursued. Some of its progeroid features may result from developmental abnormalities and others from postmaturational degenerations. The overall features include a short life span, growth retardation, testicular atrophy (or maldevelopment), pulmonary emphysema, loss of Purkinje cells of the cerebellar cortex, premature involution of the thymus, calcific forms of arterioslcerosis and ectopic deposits of calcium in other tissues, osteoporosis, skin atrophy, and lipodystrophy.

Unimodal Progeroid Syndromes

Some genetic mutations appear to accelerate certain features of aging only within a single tissue. There are a very large number of these conditions, which might be referred to as unimodal progeroid syndromes. Here only three examples are considered: one that has a major impact on sun-exposed skin, one that results in an early onset of the most common form of dementia, Alzheimer's disease, and another that results in early-onset Parkinson's disease.

Xeroderma pigmentosum While AT patients are hypersensitive to ionizing radiation, xeroderma pigmentosum (XP) patients are hypersensitive to forms of ultraviolet light (UV). Since, in the real world, some degree of exposure to sunlight is virtually inevitable, old people develop varying degrees of sun-mediated degenerative and proliferative changes in sun-exposed skin. These changes include degeneration of collagen and elastin in the dermis. What is life threatening, however, is the premalignant and, eventually, malignant changes in the epidermis. Ocular involvement can also occur, including ocular neoplasms. There are a number of genetic variants of XP; all impair the ability of cells to repair DNA.

Familial Alzheimer's Disease (FAD) Some studies have suggested that almost half of all community-dwelling US residents over the age of 85 years have the signs and symptoms of probable Alzheimer's disease. It is thus by far the most common disorder of the aging central nervous system. Three groups of families have been discovered in which a single

dominant mutation segregates with an early onset of the disease – usually defined as presenting before the age of 60, sometimes presenting as early as the late 20s. The three affected genes are *APP* (coding for the β amyloid precursor protein, the same gene suspected of being responsible for the dementia of DS subjects), *PS1* (presenilin 1), and a closely related gene called *PS2* (presenilin 2). While these families are quite rare, biochemical genetic studies resulting from these discoveries have led to a leading hypothesis for how common, so-called sporadic forms of the disease develop. This hypothesis implicates a key role for a small peptide derivative of the *APP* gene product known as A-beta 42. It is thought to develop as a minor product of metabolism, eventually forming an oligomeric molecule that is toxic to neuronal synapses. With normal genes for this metabolism, it takes many decades for the neurotoxic effects of this peptide to reach some phenotypic level of expression, thus escaping the force of natural selection. The process is accelerated, however, in DS and in FAD.

Familial Parkinson's Disease (FPD) During normative aging there is a gradual loss of dopaminergic neurons from a small, pigmented pair of structures in the midbrain. The rates of loss vary among individuals so that, for some, the masked facies and movement disorders that characterize Parkinson's disease emerge late in the life span. In the past few years there has been unprecedented progress in defining a series of rare gene mutations that lead to early-onset forms of this common disorder of aging, thus opening the door to a detailed understanding of mechanisms. There are currently 11 genetic loci implicated in its pathogenesis (*PARK* 1–11). This research has implicated potential roles for such processes as oxidative and nitrosative stress, dysfunctional mitochondria, the accumulation of altered proteins and a malfunctioning system for ridding cells of altered proteins. Environmental factors are clearly of importance, as evidenced by the emergence of a variant of the disease among large numbers of individuals affected by the 1918 influenza pandemic and the more recent discovery that a chemical by-product of an illicit street drug can cause the disease to appear almost overnight. Experiments have shown that an agent that damages mitochondria, rotenone, can also lead to marked loss of dopaminergic neurons.

See also: Achievement; Dementia: Alzheimer's; Mitochondria and Aging; Parkinson's Disease; Theories of Aging: Biological.

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Productivity and Age

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Glossary

Workforce Demographics – The proportion of the labor force represented by different ages and abilities.

Introduction

A number of demographic and social trends – including the aging of the population, changes in the labor force participation of younger workers, the aging of the Baby Boom cohort, and changes in retirement policies, programs, and behavior – are contributing to a renewed interest in older workers and the topic of aging and work. According to data reported by the US Administration on Aging in 2002, in the year

2000 the number of persons aged 55 and older in the US population was about 56 million – a 50% increase since 1900. By 2020, there will be about 120 million people in the United States in this age group, representing almost 40% of the population.

Data from the US General Accounting Office also indicates that in the near future, older people will also represent a significant proportion of the labor force. By 2010 the number of workers age 55 and older will be about 26 million, a 46% increase since 2000, and by 2025 this number will increase to approximately 33 million (**Figure 1**). Although labor force participation rates are projected to be slightly greater for older women than for older men, in contrast to previous decades the labor force participation rate for older males is increasing. For example, in 1995, about 66% of males age 65 were out of the labor force as compared to 61% in 2001. Importantly, there will also be an increase in the number of workers over the age of 65.

This change in workforce demographics is largely due to the aging of the Baby Boomers, changes in Social Security and retirement policies, and a more recent trend toward longer labor force participation – including postretirement jobs – among older people. Retirement from one's full-time, primary career job can no longer be assumed to occur at the time of workers' eligibility for Social Security benefits or to mean the total cessation of paid employment. Most older workers, according to a variety of studies, say that they would prefer to continue to be engaged in some kind of work following their retirement, and a significant number of full-time retirees say they would like to be employed. Furthermore, as the Baby Boomers start reaching retirement age, because of lower birth rates at the end of the twentieth century certain industries and occupations will find the available labor pool inadequate. Thus, many companies will be looking to older adults to fill employment needs. In addition, the retirement of the Baby Boomers is putting corporate knowledge at risk. Because of an increasingly knowledge-based economy, knowledge is considered to be a critical organizational asset. To help preserve this asset many countries around the world, such as the UK, are developing programs to encourage the retention of older workers.

Clearly the issue of aging and work is highly significant, and there is a need to develop strategies to prepare for and accommodate an aging workforce. This requires understanding (1) the characteristics of the older workforce and the growing older nonworkers, (2) the potential implications of aging for work performance, and (3) the technological and social characteristics of existing jobs and work environments. This article discusses what is currently known about older workers and productivity. An emphasis is placed on technology, given the proliferation of technology in today's work environments. Initially, a brief profile of today's elderly is provided.

Characteristics of Older Workers

In general, older Americans today are healthier, more diverse, and better educated than previous generations. The percentage of adults aged 65 and older who have completed high school has substantially increased, as has the number of older adults who have at least a bachelor's degree. Increased levels of education should prove to be beneficial to older workers, as higher levels of education are generally

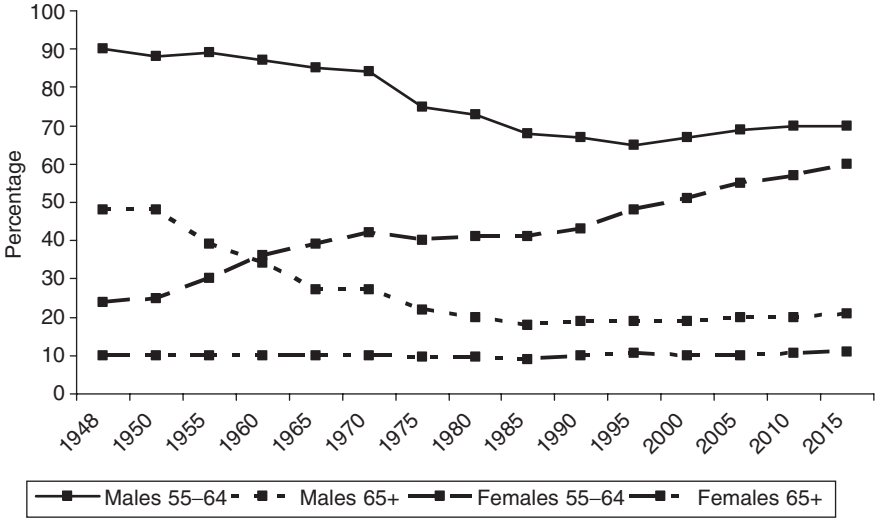

Figure 1 Labor force participation rates for older workers, by sex, 1948–2015. From US Department of Labor Bureau of Labor Statistics using the Current Population Survey (2001).

linked to increased employment opportunities, especially in today's work environments. The influx of technology into the workplace and the transition to a knowledge-based economy are creating a need for workers who are highly skilled. For example, the expansion of information technologies implies a need for workers with technical skills to operate, program, and repair technical systems. Even workers in non-technical jobs are expected to have some experience with computer applications. Thus, in addition to formal education, knowledge of technical applications is also important to employment opportunities. In addition, technology has led to an explosion in information and has enabled more data to become available at faster rates than ever before. This is turn has increased demand for workers with high-level cognitive skills, such as problem solving, analytic reasoning, and communication skills. To this end, the term knowledge worker has evolved.

On some indices, today's older adults are also healthier than previous generations. The number of people 65 and older reporting very good health and improvements in physical functioning, such as ability to walk a mile or climb stairs, has increased in recent years. Disability rates among older people are also declining. However, the likelihood of developing a disability increases with age, and many older people have at least one chronic condition (the most common being arthritis, hypertension, hearing impairments, chronic joint symptoms, heart disease, and cancer) (**Figure 2**). Cognitive and memory impairments also increase with age. Disability rates among older adults have important implications for workplace and job design. Employers may need to adapt workplaces or provide adaptive equipment or technology (such as low vision aids) to workers who have functional limitations. Generally, labor force participation rates are lower and retirement rates are higher for people with chronic conditions.

Consistent with demographic changes in the US population as a whole, the older population is also becoming more ethnically diverse. The greatest growth will be seen among Hispanic persons, followed by non-Hispanic Blacks. Work policies, programs, and services will require greater flexibility to accommodate this diverse population.

Finally, there are more older women than men, and the proportion of the population that is female increases with age. The higher percentage of older females may have implications for employment, since in recent years older women have been more likely to continue working or return to work than older men. Women are also more likely than men to be involved in caregiving responsibilities. According to recent data from the Family Caregiver Alliance, about 25 to 35% of all workers report that they are currently providing, or have recently provided, care to someone 65 or older and the majority of these workers are females. Working caregivers often suffer many work-related difficulties due to their caregiving roles. For example, many caregivers report the need to re-arrange their work schedule, decrease their hours, or take an unpaid leave in order to meet their caregiving responsibilities. Thus, employers need to provide more flexible work arrangements to accommodate this growing proportion of the workforce.

There are a number of changes in abilities associated with normal aging that have implications for work productivity. Currently, about 14 million people in the United States suffer from some type of

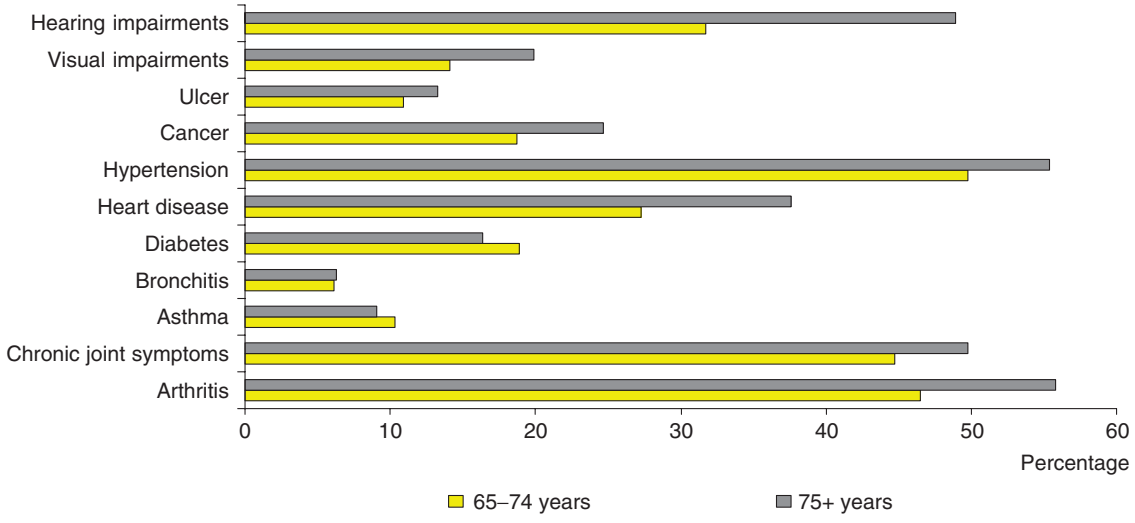

Figure 2 Selected diseases and conditions in the US population by age 2004. Data form Summary Health Statistics for the US Adults. National Health Interview Survey 2004. Vital and Health Statistics Series 10 (228), 2006.

visual impairment, and the incidence of visual impairment increases with age. Although most older adults do not experience severe visual impairment, they may experience declines in vision that affect their ability to perceive and comprehend visual information. This has vast implications for today's computer-oriented workplace, given that interaction with computer systems is primarily based on visually presented information. Age-related changes in vision also have implications for the design of written instructions and manuals and lighting requirements.

Many older adults also experience some decline in audition that has relevance to work settings. For example, older people may find it difficult to understand synthetic speech, as this type of speech is typically characterized by some degree of distortion. High-frequency alerting sounds such as beeps may also be difficult for older adults to detect. Changes in audition may also make it more difficult for older people to communicate in noisy work environments.

Aging is also associated with changes in motor skills, including slower response times, declines in ability to maintain continuous movements, disruptions in coordination, loss of flexibility, and greater variability in movement. As previously noted, the incidence of chronic conditions such as arthritis also increases with age. These changes in motor skills may make it difficult for older people to perform tasks, such as assembly work that requires small manipulation, or to use current input devices, such as a mouse or keyboard. For example, older people have more difficulty performing mouse control tasks (pointing, clicking, double-clicking, and dragging) than younger people, and age-related changes in psychomotor abilities such as manual dexterity are related to performance differences.

Older adults also tend to have reduced strength and endurance. These are population mean differences, and there is a great deal of variability in muscle groups, in types of muscular performance, and between individuals. However, in general older adults are less able to perform physically demanding jobs.

Age-related changes in cognition also have relevance to work activities, especially in tasks that involve the use of technology. Declines in working memory may make it difficult for older people to learn new concepts or skills or recall complex operational procedures. Declines in attentional capacity may make it difficult for an older person to perform concurrent activities or switch their attention between competing displays of information. They may also have problems attending to or selecting task targets on complex displays. Also, because of changes in processing speed, highly paced work may be unsuitable for older workers.

However, the picture is not all one of decline. There is clear evidence that general knowledge and domain-specific knowledge (e.g., occupational knowledge) increases well into middle-age and beyond, and this knowledge may compensate for age-related declines in other cognitive abilities such as working memory. In fact, the literature suggests that there is a relationship between standard measures of component cognitive abilities and job performance. Thus, one would expect to find age-related declines in work performance. However, as discussed later, there is little evidence that older workers are less productive than younger workers. One explanation for this is that the ability measures are not assessing the abilities needed for particular jobs. Another explanation is that the measures fail to capture the complexity of work situations. For many types of work tasks, older people are able to use their expertise and contextual support to compensate for age-related declines in abilities. Use of compensatory strategies is not possible when performing psychometric tests that are relatively novel and place a heavy emphasis on test taking and academic skills as opposed to acquired knowledge. As previously noted, knowledge is an extremely important commodity in today's work environment, and a knowledge preservation problem is plaguing many industries.

In summary, although there is a great deal of information about aging as a process, there are limited data on the practical implications of age-related changes in abilities for work activities. The majority of studies regarding the impact of age-related changes in abilities are based on laboratory tasks. Laboratory tasks do not capture the contextual elements that are present in work environments and may not allow older people to evoke compensatory strategies that are used in real-world settings. It is also important to recognize that aging is associated with substantial variability and that older adults as a group are very heterogeneous. For many indices of performance there are greater differences within the older population than between older and younger age groups. Thus, although we can discuss age-related trends in abilities, predictions about an individual's ability to learn a new skill or perform a particular job should be based on that individual's functional capacity relative to the demands of the job or skill as opposed to chronological age.

Aging and Work Productivity

Common beliefs about older workers include beliefs that they are physically unable to do their job; have a high rate of absenteeism; have a high rate of

accidents; are less productive, less motivated, and less receptive to innovations than younger people; and are unable to learn. While these are rather commonly held beliefs, there are few actual data to support these assumptions; in fact, most research studies indicate that these stereotypes are inaccurate.

The available data concerning age and productivity are limited, especially for technology-based jobs. Several extensive reviews of aging and work productivity for both blue collar and white collar jobs have been conducted. The general conclusion of these reviews is that there is little evidence to suggest that productivity declines with age. Instead, it appears that the relationship between age and work productivity is quite complex and is dependent on the type of performance measure, the nature of the job, and other factors such as experience. Furthermore, many jobs do not require performance at full capacity, and there is tremendous variability in performance for both younger and older people. In terms of creative work, the relationship between age and productivity (the quantity of creative work), for both the artistic and scientific fields, is generally one in which productivity increases until around age 40 and then declines slowly with age. However, there are three important caveats to this trend: (1) the exact age location of the peak of productivity and rate of change in productive performance depends somewhat on the field of endeavor; (2) there are numerous examples of creative work by people in the later decades; and (3) there are large individual differences in the change in productivity with age.

With respect to other measures of job behavior, the findings, while limited, are more conclusive. Older workers tend to have lower accident rates than younger workers; however, older workers tend to remain off the job longer if they are injured. Absenteeism and turnover rates are also lower for older adults.

Overall, the relationship between age and work productivity is complex and far from understood. Many studies examining this issue involve small samples or restricted age ranges or are cross-sectional, which may result in age effects being confounded with factors such as experience, education, or exposure to technology. Studies that rely on supervisory ratings of performance may be biased if the rater has negative attitudes about older workers. The results also vary according to the type of task and type of performance. Finally, the number of recent studies conducted in actual employment settings has been limited. It is reasonable to conclude that chronological age is associated with a host of age-related changes in processes and lifestyle patterns that have diverse and indirect effects on work outcomes. It is also important to recognize that many older adults engage in other forms of productive activities outside of the workplace, such as mentoring, volunteerism, or continuing education.

Another important factor to consider when addressing the topic of age and productivity is worker motivation. A number of authors have recently concluded that age-related changes in motivational variables play a key role in work outcomes for middle-aged and older people. Yet there are few empirical studies that have examined the impact of the effects of aging and adult development. A recent review of the literature suggests that work motivation in the later years generally follows the same pattern as work motivation for younger adults, such that the allocation of resources will be given to work behaviors that build on competencies, promote self-efficacy, and result in desired outcomes. The major age-related differences in motivation may relate to differences in competencies, and as such motivation of older workers may be enhanced by employing organizational practices that take into account normative changes in adult development – e.g., practices that capitalize on the domain knowledge and expertise of the older worker.

The Implications of Technology for Older Workers

A discussion on age and productivity would be remiss if it did not consider the impact of technology on work and employment opportunities. Today, technology is pervasive in the workplace, and most workers need to interact with some type of technology in the day-to-day performance of their job.

Given the widespread use of technology in most occupations, one important issue concerns how the influx of technology will affect employment opportunities and the productivity of older workers. This issue is particularly important for today's cohort of older workers, as they have not had the same exposure to technology that younger people have had. However, despite cohort differences, technology will continue to be a pertinent issue for future generations of older adults, as technology is dynamic and continuing to develop at an unprecedented rate.

In essence, technology influences the types of jobs that are available, creating new jobs and opportunities for employment for some and eliminating jobs and creating conditions of unemployment for others. Technology also changes the way in which jobs are performed and alters job content and job demands. Often, existing job skills and knowledge become obsolete and new knowledge and skills are required. As

previously noted, there is a greater emphasis on cognitive skills such as information integration, problem solving, and communication. Workers also need to learn to operate technical systems and new ways of performing jobs. This will hold true for future generations of older adults, as technology by its nature is dynamic. For example, there have been dramatic changes in the design of cell phones, portable computers, input devices, and personal organizers over the past several years.

The issues of skill obsolescence and worker retraining are highly significant for older workers, as they are often bypassed for training or retraining opportunities and may also be less willing to invest in retraining, as they may have a decreased expectancy of obtaining valued outcomes (such as promotion) or the value of these outcomes may diminish with age. A commonly held belief is that older people are resistant to change and have negative attitudes toward the use of technology. However, the available data dispute this stereotype and indicate that in general older people are receptive to using technology if they perceive the technology as useful, the technology is easy to use, and they are provided with adequate training and support. While they may experience more anxiety and less technology efficacy, older people's attitudes toward technology and comfort using technology are largely influenced by experience and the nature of their interactions with these systems.

Experience with computers generally increases user comfort and confidence. Although there are a number of settings, such as the workplace, the home, health-care settings, and service settings, where older people are likely to encounter technology, such as computers, use of technology among people over the age of 55 is still low compared to other age groups. Furthermore, although the use of the Internet is increasing among older people, it is still significantly lower than usage among other age groups (**Figure 3**). The Pew Internet and American Life Project reported that in 2004 about 22% of Americans aged 65 or older reported having access to the Internet, in contrast to 58% of Americans age 50–64 and 75% of those aged 30–49. In addition, use of the Internet within the older age cohorts is still predominantly restricted to white, highly educated seniors who live in households with higher incomes.

Problems with usability may also make it difficult for older workers to successfully interact with technology. Unfortunately, to date designers of most systems have not considered older adults as active users of technology, and thus many interfaces are designed without accommodating the needs of this population. Usability problems include poor screen design, poor input device design, complex commands and operating procedures, and inadequate training and instructional support. Although the usability of systems has improved substantially, current interfaces still exclude many people, such as those who are older or those with disabilities, from effective interaction with technology.

A number of studies have examined the ability of older adults to learn to use technology such as computers. These studies span a variety of computer applications and also vary with respect to training strategies such as conceptual versus procedural training. The influence of other variables, such as attitude toward computers and computer anxiety, on learning has also been examined. Overall, the results of these studies indicate that older adults are, in fact, able to use technology such as computers for a variety of tasks. However, they are typically slower to acquire

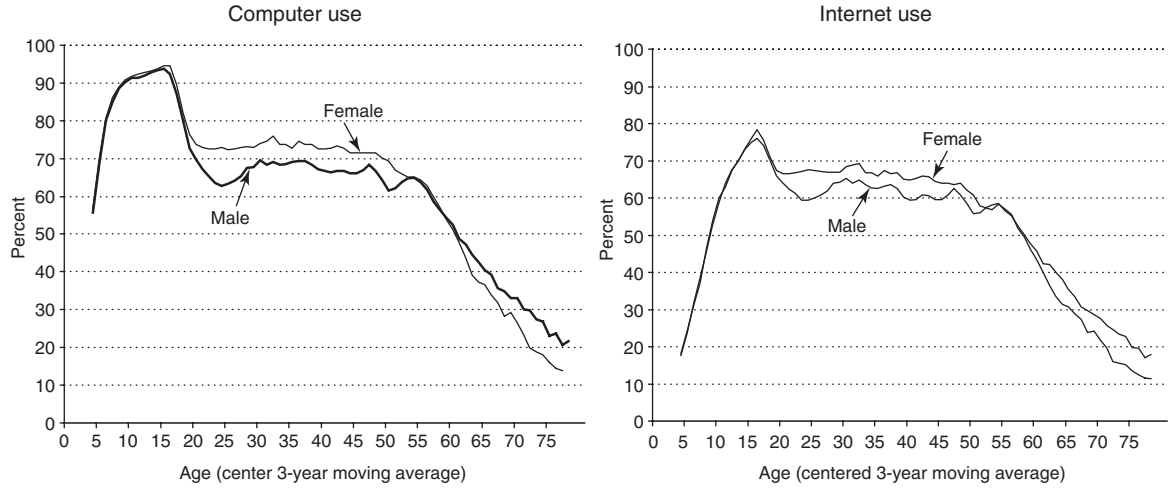

Figure 3 Computer and Internet use distribution by age and gender. From NTIA and ESA, US Department of Commerce, using US Census Bureau Current Population Survey Supplements.

new skills than younger adults and generally require more help and hands-on practice. Also, when compared to younger adults on performance measures, older adults often achieve lower levels of performance. However, the literature indicates that training interventions can be successful in terms of improving performance and points to the importance of matching training strategies with the characteristics of the learner. Clearly, greater attention needs to be given to the design of training and instructional materials for older learners. The potential use of technology as a training aid also needs to be examined. For example, older people may benefit from multimedia systems or interactive online training programs that allow for self-paced learning. However, careful attention needs to be given to the design of such packages. The current cohort of older adults might also need training on basic concepts such as mouse and windows management, in addition to training on the application area of interest. Finally, employers need to ensure that older adults are provided with access to retraining programs and incentives to invest in learning new skills and abilities. Consideration also needs to be given to the scheduling and location of training programs and potential for industry and community partnerships.

There have only been a handful of studies that have examined the ability of older people to perform computer-based tasks that are common in work settings. Generally, these data suggest that overall older adults are willing and able to perform these types of tasks. However, there may be age differences in the performance of some tasks such as data entry that emphasize speed and accuracy of performance. Importantly, the data also indicated that similar to other age groups, there is considerable variability in performance of older people and that with task experience performance improves for people of all ages. In addition, the data clearly show that usability issues have an impact on performance and that design interventions such as redesigning the interface, providing on-screen aids, and reconfiguring the timing of the computer mouse can result in performance improvements. Finally, the data indicate that it is important to provide people (especially those with limited technology experience) with training on the use of the technology as well as the task.

Summary

The topic of aging and work is increasingly important given current demographic trends, but the empirical data regarding the impact of aging on work performance are limited, especially for present day jobs and those likely to exist in the public sector in the future. There is a critical need for further research in this area.

Overall, we need more information on the relationship between age-related changes in functioning and the specific skill requirements of jobs. Although there are age-related declines in some functions, changes are gradual and most jobs do not demand constant performance at the level of maximum capacity. The majority of the population of older adults remains healthy and functionally able until very late in life. One important area of needed research is developing a knowledge base that links age-related changes in skills and abilities to specific skill requirements of jobs. For example, currently, the relationships among aging, cognition, and work productivity are unclear. A more complete understanding of these relationships would help direct the development of intervention strategies for older workers. This underscores the need to investigate differences in health, abilities, workplace performance, and technology use by cohort and by finer age categories, as well as to follow particular subgroups over time.

We also need sound, research-based information about the impact of technology on an aging workforce and how technology might be used to promote employment opportunities for older people. In addition, we need knowledge about how technology can be used to facilitate career and employment transitions. It is also important to understand how to design technology so that it is useful and usable for older adult populations, especially those with some type of impairment. All too often designers restrict their vision of user groups to young, able-bodied populations. Research also needs to be directed toward examining the cost-effectiveness of technological interventions.

In general, research attention directed toward those aspects of work that could become more difficult, less productive, or less satisfying with age could make a worthwhile contribution to improving the work life of older adults. Such research would also help to assure the availability of appropriate employment opportunities for older people and broaden the pool of potential employees for public agencies competing for increasingly scarce labor.

See also: Caregiving and Caring; Human Factors Engineering and Ergonomics; Learning; Skill Acquisition; Work and Employment: Individual.

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Prostate

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Glossary

Autocrine – Pathway in which a cell responds to the same peptide growth factor that it simultaneously produced.

Exocrine Gland – A gland that releases a secretion external to the surface of an organ by means of a canal or duct.

Paracrine – Pathway in which a peptide growth factor is elaborated by one cell type but affects a different neighboring cell type.

Introduction

The prostate functions as a reproductive exocrine organ and functions to prevent urinary tract infections. However, the prostate is most noted for the frequency with which it is the origin of benign and malignant neoplasms and infectious diseases in aging men. The most important of these diseases are prostatitis, benign prostatic hyperplasia, and prostate cancer. This article will review the prostate in health and disease with an emphasis, where possible, on the gerontological aspects of prostate disease. (*See* Renal and Urinary Tract Function.)

Anatomy

The adult prostate gland weighs an average of 20 g, is approximately the size of a walnut, and surrounds the urethra just below the bladder neck as shown in **Figure 1**. The posterior surface of the prostate can be palpated by a digital rectal exam. The prostate is composed of tubuloalveolar glands and stroma. The fluid produced by the prostate glands drains into 20 to 30 ducts that enter the urethra at or distal to a bulge in the distal prostatic urethra called the verumontanum. On each side of the verumontanum are the ejaculatory ducts, which are the conduits for sperm from the testicles and seminal fluid from the seminal vesicles. The prostate stroma surrounds the prostate glands and is made up of smooth muscle and fibroblasts.

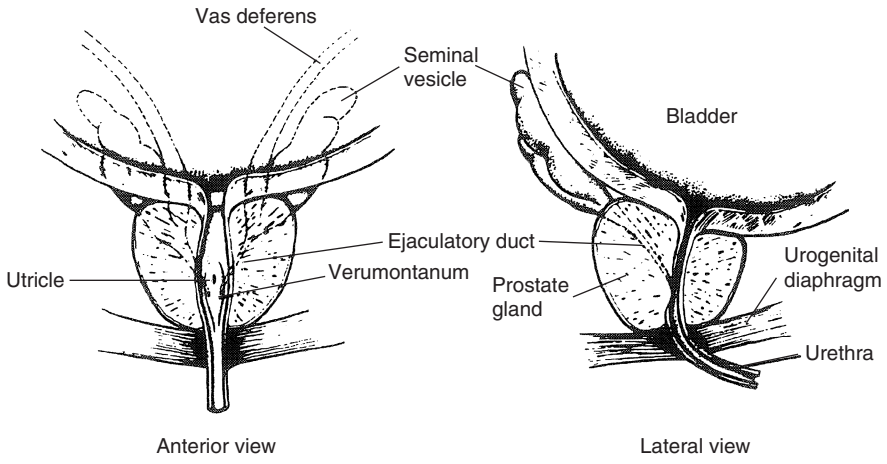

Figure 1 The prostate surrounds the urethra just below the level of the bladder neck. Fluid from the vas deferens and seminal vesicles drains into the ejaculatory ducts that enter the urethra just lateral to the verumontanum. The verumontanum is a midline bulge at the distal prostatic urethra. From Goluboff ET, Stifelman MD, and Fisch H (1995) Ejaculatory duct obstruction in the infertile male. *Urology 45*(6): 925. Used by permission of Elsevier.

Physiology

Reproduction

The prostate is an exocrine gland (excretes fluid) and has no known endocrine (hormonal) function. The exocrine secretions make up 15% of the ejaculate volume, but this fluid in itself is not necessary for fertility. The prostate along with the bladder neck and prostatic urethra play a critical role in coordinated antegrade sperm delivery during ejaculation. At the time of ejaculation, sympathetic nerve fibers innervating the $\alpha 1$ receptors in the smooth muscle in the prostate, bladder neck, and vas deferens cause emission of seminal fluid and sperm into the prostatic urethra, and closure of the bladder neck and prostatic urethra. This closure prevents the sperm and seminal fluid from going into the bladder during ejaculation and is necessary for normal ejaculation.

Infection – Host Resistance

The prostate glands produce numerous substances that are continuously released into the urethra. These include zinc, citric acid, calcium, phosphoryl choline, prostatic acid phosphatase, and prostate-specific antigen (PSA). The prostatic fluid has the highest concentration of zinc in the body, and zinc is known to be an antibacterial factor. Ongoing release of zinc by the prostate may play a role in preventing urinary tract infections. There is a great deal of popular literature purporting that intake of zinc is beneficial in preventing urinary infections and prostate disease, but this is unsubstantiated.

Prostatitis

Prostatitis, or inflammation of the prostate, is a term used to describe infectious and non-infectious inflammatory conditions of the prostate. Prostatitis may occur in men from puberty through adulthood. Patients may present with a variety of symptoms, including pain in the perineum, low back, and suprapubic area, painful ejaculation and urination, and a decrease in the force of the urinary stream. There are four different types of prostatitis that are described herein.

Etiology

A variety of theories have been proposed to explain the cause of prostatitis. These include urinary reflux into prostatic ducts, alterations in the secretory products of the prostate, and the presence of infected prostatic calculi. Unfortunately, we do not understand why men develop prostatitis, and as a result, physicians are frequently unsuccessful and frustrated in their attempts to treat patients. Not surprisingly, patients also have a poor understanding of their disease and are frequently unhappy with treatment results.

Bacterial Prostatitis

The most common organism causing bacterial prostatitis is *Escherichia coli,* which is also the most common pathogen causing urinary tract infections. Indeed, bacterial prostatitis is the most common cause of urinary tract infections in older men. Other organisms causing bacterial prostatitis include

Proteus, Klebsiella, Enterobacter, Pseudomonas, Serratia, and less frequently, *Enterococcus*.

Acute Bacterial Prostatitis

Acute prostatitis is an acute febrile illness associated with constitutional symptoms as well as the prostatitis symptoms previously described. On examination, patients are acutely ill and the prostate is exquisitely tender and should not be palpated with any force. Pathologically the prostate is infiltrated with neutrophils. These patients require admission to the hospital and intravenous antibiotics. If patients have urinary retention or severe obstructive voiding symptoms, a suprapubic tube is placed into the bladder to drain the urine to avoid traumatizing the prostate with a urethral catheter. If the infection fails to resolve then studies are performed to rule out a prostatic abscess, which may require drainage. Treatment for acute prostatitis is quite successful, and subsequent urologic studies are directed towards identifying a source for the infection.

Chronic Bacterial Prostatitis

A diagnosis of chronic bacterial prostatitis is based on positive cultures of prostatic fluid obtained by digitally massaging the prostate and culturing the expressed fluid that exits the meatus. Microscopy on this fluid shows >10–20 white blood cells per high-power field. A small volume of urine is voided after the prostate massage, and the bacterial count of this culture exceeds that of the urine voided prior to the prostate massage. Treatment consists of 1 month of oral antibiotics based on bacterial sensitivity testing. The ideal antibiotic must have good coverage of Gram-negative bacteria and must be lipid soluble to penetrate the prostate tissue. The quinolone antibiotics have these characteristics and are effective in the majority of cases of bacterial prostatitis. For reasons that are unknown, some infections persist and do not respond to treatment.

Chronic Non-bacterial Prostatitis

The diagnosis of chronic non-bacterial prostatitis is based on the expressed prostate fluid showing >10–20 white blood cells per high-power field but no documentation of any bacterial infection. These patients present with symptoms of prostatitis, but the etiology of the inflammation is unknown. Physicians explain to these patients that there is inflammation of the prostate the causes of which are not understood. In general, physicians will try a course of empiric oral antibiotics, usually the quinolones, for 1 month. If symptoms do not resolve then treatment becomes difficult because the etiology of the disease is not understood. Treatment options include frequent hot sitz baths, anti-inflammatory agents, and in some patients, diet alteration, if they find that their symptoms are exacerbated by spicy foods, caffeine, or alcohol.

Prostatodynia

Prostatodynia, literally prostate pain, is a diagnosis given to patients with prostatitis symptoms but no evidence of infection or inflammation in the prostate fluid. Typically these patients are young to middle-aged and suffer a great deal from their symptoms. Empiric antibiotics and supportive treatment as described in the chronic non-bacterial prostatitis section are prescribed with varying results. In some of these patients, non-relaxation of the pelvic floor muscles and hyperplasia of the bladder neck has been documented. Urodynamic studies to measure the pressure generated in the bladder during voiding may be indicated in patients with prostatodynia, and if bladder outlet obstruction from bladder neck hyperplasia is documented, these patients may benefit from incision of the bladder neck. Thermotherapy of the prostate is also being studied for patients with non-bacterial prostatitis and prostatodynia, and uncontrolled trials have shown some success with this treatment. Unfortunately, the etiology of prostatodynia remains quite speculative.

Benign Prostatic Hyperplasia

Benign prostatic hyperplasia (BPH) is the most common benign tumor of adult men and is a major factor affecting the health of older men. BPH is a pathologic term referring to growth of the glandular and stromal elements in the prostate. With this growth of the prostate, men can develop bothersome urinary symptoms and complications resulting from bladder outlet obstruction. This section will review the etiology, physiology, and clinical aspects of BPH.

Incidence

Men begin to develop BPH in their 30s, and the incidence increases with age, as shown in **Figure 2**. Over 50% of men older than age 50 have BPH, and 75% of men in their eighth decade have BPH. The urinary symptoms caused by bladder outlet obstruction, termed prostatism, occur in 25% of men 55 years of age and occur in 55% of men aged 75.

Etiology

The two conditions necessary for BPH to develop are the aging process and testosterone production from the testicles. Men who receive an orchiectomy before

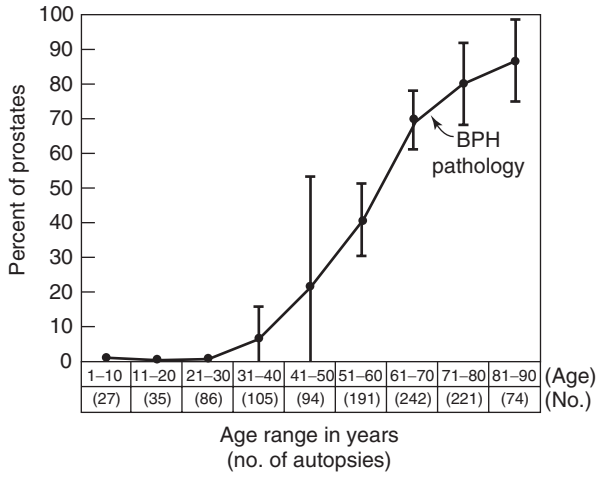

Figure 2 The prevalence of benign prostatic hyperplasia (BPH) as assessed in autopsy specimens. As men get older the prevalence of BPH increases. From Berry SJ, Coffee DS, Walsh PC, *et al.* (1984) The development of human benign prostatic hyperplasia with age. *Journal of Urology* 132: 474. Used by permission of the American Urological Association.

puberty do not develop BPH. Testosterone produced by the testicles is converted to dihydrotestosterone in the cytoplasm of the prostate stromal and epithelial cells. Dihydrotestosterone then binds to an androgen receptor, and this complex binds to specific DNA sites in the nucleus and causes protein synthesis and cell growth. As further evidence of the role of testosterone in the development of BPH, 5-α reductase inhibitors, androgen receptor blockers, and orchiectomy all cause a decrease in prostate size.

As men age, their testosterone levels decrease. The ongoing growth of the prostate can be explained in part by an increase in number of androgen receptors in the prostate with age. More recent experiments support the role of stromal and glandular interactions via growth factors in causing BPH. Basic fibroblast growth factor (FGF) and transforming growth factor (TGF) beta have been shown in tissue culture to act as autocrine and paracrine factors leading to BPH. Researchers are just beginning to understand the causes of BPH in aging men.

Physiology

Benign prostatic hyperplasia occurs in both the glandular and stromal elements of the prostate. The enlarging prostate can cause bladder outlet obstruction by physically blocking the prostatic urethra, termed *static obstruction*. In addition, contraction of the smooth muscle in the prostate stroma and capsule causes dynamic bladder outlet obstruction. This contraction is under the influence of sympathetic nerve fibers innervating the α1 receptors in the smooth muscle. Pharmacologic therapy that blocks the α1 receptors is extremely effective in alleviating symptoms of BPH and will be discussed later.

Table 1 Prostatism symptoms

Obstructive	*Irritative*
Difficulty initiating stream	Frequency
Slow force of stream	Urgency
Hesitancy (stream starts and stops)	Urgency incontinence
Straining to urinate	Dysuria
Feeling of incomplete bladder emptying	Nocturia

With bladder outlet obstruction from BPH, men may develop obstructive voiding symptoms including a decreased force of their urinary stream and difficulty emptying their bladder. In response to the bladder outlet obstruction, the smooth muscle in the bladder wall hypertrophies and the bladder wall thickens. This causes a decreased functional capacity of the bladder, and men develop the so-called irritative voiding symptoms that include urinary frequency, urgency, and nocturia. These irritative symptoms are usually more bothersome to patients than their obstructive symptoms, and can interfere with their daily activities and their sleeping.

A small percentage of patients will develop complications from their BPH, including recurrent urinary tract infections, gross hematuria, urinary retention, and obstructive uropathy. These patients usually require surgical rather than medical management of their BPH.

Diagnosis

The diagnosis of benign prostatic hyperplasia is based on clinical assessment and does not require a biopsy of the prostate tissue. The history begins with assessment of the presence and severity of the obstructive and irritative voiding symptoms shown in **Table 1**. To this end, the American Urologic Association (AUA) developed the AUA Symptom Score shown in **Figure 3**, a scientifically valid and reproducible questionnaire to assess the severity of prostatism symptoms and to assess the efficacy of treatment. The AUA Symptom Score can be quite helpful in managing patients with BPH. The symptom score also has limitations in that it does not diagnose prostatism, and any number of causes of voiding dysfunction can cause an elevated AUA Symptom Score. In addition, the AUA Symptom Score does not assess the degree of bother that patients have as a result of their symptoms, and some patients have a high AUA score but are not troubled by their symptoms and do not want any type of treatment.

The history of patients with suspected BPH is also directed at elucidating any other etiologies for the

The AUA symptom index

Question	Not at all	Less than 1 time in 5	Less than half the time	About half the time	More than half the time	Almost always
1. During the last month or so, how often have you had a sensation of not emptying your bladder completely after you finished urinating?	0	1	2	3	4	5
2. During the last month or so, how often have you had to urinate again less than 2 hours after you finished urinating?	0	1	2	3	4	5
3. During the last month or so, how often have you found you stopped and started again several times when you urinated?	0	1	2	3	4	5
4. During the last month or so, how often have you found it difficult to postpone urination?	0	1	2	3	4	5
5. During the last month or so, how often have you had a weak urinary stream?	0	1	2	3	4	5
6. During the last month or so, how often have you had to push or strain to begin urination?	0	1	2	3	4	5
7. During the last month, how many times did you most typically get up to urinate from the time you went to bed at night until the time you got up in the morning?	None	1 time	2 times	3 times	4 times	5 or more times*
	0	1	2	3	4	5

AUA symptom score = sum of questions 1 to 7.

Figure 3 The American Urological Association Symptom Score is a standardized questionnaire that gives a numeric value to the severity of voiding symptoms. Voiding symptoms are considered mild if the score is 0–7, moderate if the score is 8–19, and severe if the score is 20–35. From Barry MJ, Fowler Jr. FJ, O'Leary MP, *et al.* (1992) The American Urological Association symptom index for benign prostatic hyperplasia. *Journal of Urology* 148(5): 1549. Used by permission of the American Urological Association.

patient's voiding dysfunction. The differential diagnosis for voiding dysfunction is extensive and includes malignancy, infection, neurologic diseases, other causes of bladder outlet obstruction, such as urethral stricture disease, and side effects of various medications on the bladder and bladder outlet.

Physical examination includes a careful digital rectal exam of the prostate to assess for any nodules suggestive of malignancy and to rule out prostatitis. A common misconception is that the size of the prostate correlates with urinary symptoms or with the need for some type of intervention. In fact, the size of the prostate does not correlate with the incidence or severity of prostatism symptoms and in no way correlates with the risk of malignancy. The physical exam also includes palpation for a distended bladder, examination of the meatus to rule out meatal stenosis as a cause of bladder outlet obstruction, and a thorough neurologic exam.

All patients with prostatism symptoms should have a urinalysis to rule out infection and microscopic hematuria, and a serum creatinine to rule out renal failure. There is ongoing debate concerning whether a PSA is necessary in all patients with suspected BPH. In general, we obtain a PSA in all of our patients with prostatism symptoms because the PSA appears to be more sensitive than the digital prostate exam in detecting prostate cancer. Moreover, if prostate cancer is present it would greatly change our management.

Medical Treatment

Once we establish the diagnosis of BPH, we explain to our patients about their condition and reassure them that there is no evidence of malignancy. We also explain that, unfortunately, symptomatic BPH appears to be a normal part of aging. Usually, patients are reassured to hear that there is no evidence of prostate cancer, and if their voiding symptoms are not bothersome, they will frequently elect watchful waiting and periodic checkups. If the prostatism symptoms are bothersome to the patient, we usually first offer pharmacologic treatment consisting of either $\alpha 1$ blocking agents or 5-α reductase inhibitors.

The selective $\alpha 1$ blocking agents (doxazosin, terazosin) exert their effects by relaxing the smooth muscle in the prostate stroma, capsule, and bladder neck, and thus decrease the dynamic component of the bladder outlet obstruction. In prospective randomized double-blind trials, these agents have been shown to give patients symptomatic improvement and to increase the urinary flow rate. Whereas placebo is effective at improving symptoms in about 40% of patients with BPH, $\alpha 1$ blockers are effective in about 75% of patients. Patients can notice improvement within several weeks of beginning therapy, and they must continue to take these drugs on a daily basis or else their symptoms will recur. Because $\alpha 1$ blocking agents are also effective for treating

hypertension, in some patients this one medication can treat two problems at once. These agents are tolerated well by normotensive as well as hypertensive patients, and side effects include dizziness, fatigue, and hypotension.

The other medical therapy available to treat prostatism is finasteride, a 5-α reductase inhibitor that blocks the conversion of testosterone to dihydrotestosterone. This drug causes the prostate to decrease in volume by 25% and causes a 50% reduction in the PSA at 6 months. Prospective randomized blinded trials have demonstrated that finasteride gives symptomatic improvement and causes a modest increase in urinary flow rate after at least 6 months of treatment. Side effects include impotence, decreased libido, and decreased ejaculatory volume in less than 5% of patients.

Surgical Treatment

Surgery is indicated for BPH when there is documented obstructive uropathy (kidney failure), urinary retention, recurrent urinary tract infections secondary to high postvoid residuals, or gross hematuria secondary to BPH. Surgery is also indicated for symptomatic improvement especially if pharmacologic treatment is insufficient. The gold standard technique that gives the best improvement in urinary flow rate and the best symptomatic improvement is the transurethral resection of the prostate (TURP). In this procedure the obstructing prostate tissue is resected using a cautery-wire loop through a cystoscope in the urethra. This procedure requires an anesthetic and several days of hospitalization after the procedure with an indwelling foley catheter in the bladder. The catheter is removed prior to discharge from the hospital. Several weeks of convalescence are required to allow the surgical site to heal. Most patients have retrograde ejaculation following a TURP in which the ejaculate goes into the bladder instead of out the penis during the sexual act. Other side effects are rare and include incontinence, impotence, stricture, and bleeding requiring a blood transfusion. In patients who require surgery and have extremely large prostates in excess of 100 g, an open prostatectomy is performed. In this procedure the benign obstructing prostate tissue is removed through a lower abdominal incision, while the peripheral prostate tissue and capsule are left behind.

There is a great deal of ongoing research investigating other surgical procedures to remove obstructing prostate tissue. The most promising of these techniques involves use of laser energy to either coagulate or vaporize the obstructive tissue. Laser surgery offers advantages over TURP, including less hospitalization time and less bleeding complications as well as a decreased incidence of retrograde ejaculation. TURP, on the other hand, continues to give better improvement in the urinary flow rate compared to the laser. Until more data are available concerning the type of laser energy used, the power level, and the duration of laser exposure, we continue to use the TURP for patients requiring surgical treatment of BPH.

Another technique that is actively being investigated is transurethral vaporization of the prostate, which uses a steel rollerball device to transmit high-power electrical cutting current to the prostate. This technique is purported to require less hospitalization, cause less bleeding, and be technically easier than a TURP, but controlled studies are not yet available.

Prostate Cancer

Incidence

Adenocarcinoma of the prostate is the most common internal cancer of males in the United States and is the second most common cause of cancer deaths, second only to lung cancer. The incidence of prostate cancer continues to rise each decade. Overall, men in the United States have a 9.5% lifetime risk of developing prostate cancer and a 2.8% lifetime risk of dying of prostate cancer. Clearly, prostate cancer is a major health problem in aging males. (*See* Cancer and Age.)

Etiology

As men age, the incidence of prostate cancer increases. There is a great disparity between the incidence of clinical carcinoma of the prostate (CAP) and the incidence of prostate cancer found at autopsy (occult cancer) in men who die of other causes. Autopsy studies reveal that 30% of men in their seventh decade, 40% of men in their eighth decade, and 50% of men in their ninth decade have subclinical prostate cancer. Of great interest is that only a small percentage of these men go on to develop clinical prostate cancer. The factors that cause subclinical prostate cancer to progress to clinical prostate cancer are presently under intense investigation.

Although the autopsy incidence of prostate cancer is equal in Japanese and American men, clinical prostate cancer is uncommon in Japanese men. However, when Japanese men move to the United States, the incidence of clinical CAP approaches that of Whites in one to two generations. The reason for this is not known, but research is focusing on the difference in dietary habits of Japanese and Americans. In Japan, unlike America, the usual diet is low

in fat and high in soybean. Studies in tissue culture and in mice have shown that low fat and high soybean confers protection from growth of established prostate cancer. Other environmental factors may also play a role in converting latent prostate cancer to clinical prostate cancer. (*See* Diet and Nutrition.)

Race also plays a significant role in the development of clinical CAP. Whereas the autopsy incidence of CAP in Blacks equals that of Whites in the United States, Black men have a higher incidence of clinical prostate cancer than Whites, and these cancers present at more advanced stages and have a higher mortality in Blacks. These statistics hold even when controlling for age, socioeconomic status, and the geographic area. Access to medical care, diet, and genetic factors may all play a role, and research in this area is ongoing.

In a subset of men, genetics also plays an important role in the development of prostate cancer. Men with first-degree relatives with prostate cancer have a two- to three-fold increased incidence of developing prostate cancer, and this risk increases with the number of family members affected. Therefore, inquiry into a family history of prostate cancer should be made in every man undergoing a routine history and physical examination, and patients with a positive family history need more careful follow-up.

Prostate-Specific Antigen

PSA is presently the most unique marker in cancer biology, and its discovery has revolutionized the detection, diagnosis, and treatment of prostate cancer. PSA is a glycoprotein normally produced by prostate epithelial cells and it functions to hydrolyze the coagulum of the ejaculate. Prostate cancer as well as inflammation, BPH, and prostate trauma can cause increased amounts of PSA to be released into the bloodstream. An abnormally elevated serum PSA has been shown to be more sensitive than the digital prostate exam in detecting prostate cancer. With the discovery of PSA, physicians are now detecting many more prostate cancers, and there is now a sensitive marker to measure the effectiveness of treatments. However, up to 20% of men with clinical prostate cancer have a normal PSA level, thus emphasizing the importance of the digital prostate exam.

Screening

With the discovery of PSA, numerous screening programs have been set up with the hope of detecting prostate cancer earlier. Although physicians are now detecting more early and advanced stage prostate cancers, to date there is still no evidence that prostate cancer screening has decreased the mortality from prostate cancer. This may be partly because many prostate cancers appear to be slow growing, and patients often die of other causes than their prostate cancer. Conclusions on the effectiveness of screening for CAP are forthcoming, but at this time the American Cancer Society and the AUA are recommending yearly PSA measurements and prostate exams in men beginning at age 50, and beginning at age 40 in patients with risk factors for prostate cancer.

Diagnosis and Staging

Patients suspected of having prostate cancer from an abnormal digital prostate exam or an elevated serum PSA undergo biopsy of the prostate. This is accomplished by advancing a biopsy needle transrectally into the prostate with either ultrasound or finger guidance and obtaining cores of tissue from the prostate. Transrectal ultrasound allows accurate sizing of the prostate and helps in directing the biopsy needle to specific areas in the prostate. Volumetric measurement of the prostate with ultrasound is especially important because a large volume of BPH can sometimes explain an increase in the PSA.

Once the diagnosis of CAP is made, the tissue is graded pathologically by the Geason scale, with grade 5 being the most poorly differentiated and grade 1 being well differentiated. Staging is based on the size and extent of the palpable cancer and on the metastatic workup, which includes a chest X-ray, bone scan, blood count, and liver function tests. The prostatic acid phosphatase blood test is also frequently used; elevation of the enzymatic acid phosphatase usually means the prostate cancer is advanced and cannot be cured by surgery or radiation therapy.

Treatment

The appropriate treatment depends on a broad range of factors including tumor grade and stage, the patient's 10- to 15-year life expectancy and general health, and most importantly, the patient's preference. A great deal of controversy exists regarding the best treatment for prostate cancer, and numerous ongoing studies are attempting to address this issue.

Expectant Management

Expectant management for prostate cancer consists of regular clinic visits, monitoring for the complications of prostate cancer, and treating patients for symptoms if they arise. This is the primary management used for prostate cancer in some parts of Europe and Scandinavia. Several prospective studies show that the majority of patients treated

by expectant management die of causes other than their prostate cancer, and the cancer does not impact on their life expectancy. This is because many prostate cancers grow slowly and may take decades to spread or cause symptoms. Expectant management has come under harsh criticism because a significant percentage of patients in expectant management studies go on to develop locally advanced or metastatic disease. Also, many of the patients in these studies have lower-grade, less aggressive tumors to begin with.

Radical Prostatectomy

Radical prostatectomy consists of removing the entire prostate and seminal vesicles. After the prostate is removed, the bladder neck is sutured to the urethra over a urethral catheter. Patients are hospitalized for about 3–4 days and are required to wear the urethral catheter for 2 weeks at home. Radical prostatectomy cures 60–80% of patients and is a good option in patients with a 10- to 15-year life expectancy. The cure rate of radical prostatectomy approaches 90% if the cancer is confined to the prostate gland on pathological examination. Potency can be preserved in a select group of younger patients with small tumors by sparing the nerves that run along each side of the prostate. A significant number of patients suffer from impotence and periodic urinary incontinence after the surgery, and this can impact negatively on their quality of life. On the other hand, radical prostatectomy offers the possibility of a cure of a potentially deadly cancer. If impotence and incontinence develop, various treatments are available that deal successfully with these complications.

Radiation Therapy

Radiation therapy either by external beam or by interstitial seed implantation also offers the chance for cure in patients with localized prostate cancer. Although retrospective studies suggest that surgery may offer a better chance for cure than radiation therapy, there still has not been a good prospective randomized study comparing these two treatments. It may be that many patients receiving radiation therapy in these studies are poor surgical risk patients and have more advanced disease than the patients in the retrospective surgery series, thus making these studies invalid for comparison. Although patients who receive radiation therapy suffer less impotence and urinary incontinence than patients who receive surgery, these as well as other side effects, including bowel and bladder irritation, can occur from radiation treatment.

Hormonal Therapy

The growth of prostate cancer is partly dependent on androgens produced by the testicles and adrenal glands. By either removing the testicles (orchiectomy), or giving drugs that inhibit the production of or action of androgens, prostate cancer can be put into a remission for up to several years. Unfortunately, this effect is only temporary and eventually the prostate cancer becomes independent of androgens and continues to grow.

Patients with advanced prostate cancer usually receive some form of hormonal treatment. This consists of either bilateral orchiectomy or medical therapy. The leutinizing hormone (LH)-releasing agonists leuprolide and goserelin act by preventing the release of LH from the anterior pituitary. These medications ultimately stop the production of testosterone by the testicles and are as effective as orchiectomy. Another agent, flutamide, blocks androgen receptors and prevents the binding of androgens produced by the adrenal glands and the testicles. These hormonal treatments are extremely effective in putting advanced prostate cancer into a remission for a variable period of time. Side effects of these agents include hot flushes and, most notably, impotence.

Cryotherapy

More recently, numerous medical centers are attempting to cure clinically localized prostate cancer by freezing the prostate via special probes placed in the perineum under ultrasound guidance. Patients go home the same or next day. Although many patients develop an undetectable PSA after cryotherapy, the side effects can be significant. Long-term results of cryotherapy are needed before we can recommend this treatment.

Recent Advances in Prostate Cancer

A number of recent discoveries concerning PSA deserve mentioning here. Age-specific reference ranges are now being established for PSA. As men age, the upper limit of normal for PSA increases. Whereas a PSA of 4 ng/ml was previously the upper limit of normal for the Hybritech PSA test, now for men in their 70s, a PSA of 5 or 6 ng/ml is probably within normal limits. Hopefully, this will help relieve the great anxiety these older men experience when they are told that their PSA is elevated and will prevent some unnecessary prostate biopsies from being performed.

Further technology in PSA measurement may help us better predict which patients with an elevated PSA require a prostate needle biopsy. Many men with a PSA between 4 and 10 ng/ml (normal Hybritech range 0–4 ng/ml) have a PSA elevation secondary to

their BPH and undergo needless prostate biopsies. PSA can now be measured in both a free and bound form, and it appears that the fraction of the bound PSA to the total PSA may help distinguish which of these men may have a higher likelihood of having prostate cancer and require a biopsy.

Another recent advance is in the area of molecular staging of prostate cancer. With gene amplification techniques, physicians can now detect a single PSA-producing prostate cancer cell in the bloodstream. This technology may help physicians to better detect or stage prostate cancer, and may help them evaluate better the effectiveness of various treatments of prostate cancer.

Conclusion

A number of prostate diseases including prostatitis, BPH, and prostate cancer are having a major impact on the health of aging men. For reasons that are not understood, these diseases develop as men get older. In fact, BPH and prostate cancer seem to be a normal part of aging, and many men live with mild symptoms or occult cancer and die before these diseases have a significant impact on their quality of life. Part of the art of medicine is determining when to treat patients and subject them to the side effects of medications and surgeries, and when to observe patients without any active interventions.

See also: Cancer and Age; Diet and Nutrition; Renal and Urinary Tract Function.

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Psychological Well-Being

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Glossary

Emotional Well-Being (also called Hedonia) – The balance of feelings (positive and negative) experienced in life.

Positive Functioning – Encompasses six dimensions of psychological well-being: self-acceptance, positive relations with others, personal growth, purpose in life, environmental mastery, and autonomy.

Subjective Well-Being – Emotional well-being and positive functioning.

Introduction

Social and psychological scientists have created a variety of self-report measures to tap people's subjective sense of the quality of their lives. Although research shows that people use multiple criteria to evaluate their subjective experiences, there are two general lines of research that have evolved. According to one line of well-being research, evaluations of the degree of positive feelings (e.g., happiness) experienced and perceptions (e.g., satisfaction) toward one's life overall constitute subjective well-being. A second stream of well-being research specifies dimensions of positive functioning in terms of psychological well-being and social well-being. Overall, subjective well-being consists of two broad domains – emotional well-being (hedonia) and positive functioning (eudaimonia). These domains, their conceptions and measurement, and their levels throughout the adult life span are reviewed in this article.

Varieties of Subjective, Psychological Well-Being

Hedonia: Emotional Well-Being

The emotional well-being cluster of symptoms reflects the presence and absence of positive feelings about life operationalized as evaluations of happiness and satisfaction with life and the balance of positive to negative affect experiences over a time period. Thus, emotional well-being can be conceptualized as the balance of feelings (positive and negative) experienced in life and the perceived feelings (happiness and satisfaction). Most single-item measures of life satisfaction are adaptations of Cantril's Self-Anchoring Scale, which asks respondents to "rate their life overall these days" on a scale from 0 to 10, where 0 meant the worst possible life overall and 10 meant the best possible life overall. Variants of Cantril's measure have been used extensively in numerous studies worldwide and have been applied to the measurement of avowed happiness with life. Single-item indicators and multi-item scales of life satisfaction and happiness have also been developed and employed extensively.

Most measures of positive and negative affect investigate the frequency or the duration of time that a respondent reports the experience of symptoms of positive and negative affect. For example, individuals are often asked to indicate how much of the time during the past 30 days they have felt six types of negative and six types of positive indicators of affect. Response choices for the negative affect and positive affect items shown in **Table 1** are all, most, some, a little, or none of the time. Estimates of internal reliability of the multi-item scales of satisfaction and happiness and positive and negative affect usually exceed 0.80. Studies also support a proposed factor structure of emotional well-being with a cognitive domain of avowed life satisfaction and an affective domain of happiness.

Eudaimonia: Positive Functioning

Psychological Well-Being Subjective well-being is more than the presence and absence of affective states; it also includes the perceived presence and absence of positive functioning in life. Positive functioning encompasses six dimensions of psychological well-being: self-acceptance, positive relations with others, personal growth, purpose in life, environmental mastery, and autonomy. Conceptual definitions and representative items of each dimension of psychological well-being are shown in **Table 1**.

Self-acceptance requires the maintenance of esteem for one's self, while facing complex and sometimes unpleasant personal aspects of the self. In addition, individuals accumulate a past and have the capacity to recall and remember themselves through time. Healthy individuals perceive themselves positively across the life course and accept all parts of themselves. Positive relations with others consist of the ability to cultivate warm, intimate relationships with others. It also includes the presence of satisfying social contacts and relations. Autonomy measures the degree to which people seek self-determination and personal authority, in a society that at times requires obedience and compliance. However, healthy individuals seek to understand their own values and ideals. In addition, healthy individuals see themselves guiding their own behavior and conduct from internalized standards and values.

Environmental mastery is the active engagement of the environment in order to mold it to meet one's needs and wants. Healthy individuals recognize personal needs and desires and also feel capable of taking, and feel permitted to take, an active role in getting what they need from their environments. Purpose in life captures the adult's perception of having direction in life, even when the world offers none or provides unsatisfactory alternatives. Healthy individuals see their daily lives as fulfilling a direction and purpose, and, therefore, they view their personal lives as meaningful. Last, personal growth is the ability and desire to enhance existing skills and talents and to seek opportunities for further personal development. In addition, healthy individuals are open to experience and have the capacity to identify challenges in a variety of circumstances.

Table 1 Subjective well-being traditions, dimensions, operational definitions, and representative items

Hedonia *Emotional well-being*	*Eudaimonia* *Psychological well-being*	*Eudaimonia* *Social well-being*
Affect balance: the balance of the amount of positive to negative affect experienced over a time period.	**Self-acceptance**: possess positive attitude toward the self; acknowledge and accept multiple aspects of self; feel positive about past life.	**Social acceptance**: have positive attitudes toward people; acknowledge others and generally accept people, despite others' sometimes complex and perplexing behavior.
Positive affect: symptoms suggesting the presence of pleasant feelings.		
• During the last 30 days, how much of the time did you feel cheerful; in good spirits; extremely happy; calm and peaceful; satisfied; and full of life?	• I like most parts of my personality. • When I look at the story of my life, I am pleased with how things have turned out so far. • In many ways, I feel disappointed about my achievements in life (–)	• People who do a favor expect nothing in return. • People do not care about other people's problems. (–) • I believe that people are kind.
Negative affect: symptoms suggesting the absence of unpleasant feelings.		
• During the last 30 days, how much of the time did you feel nervous; worthless; everything was an effort; hopeless; restless or fidgety; so sad nothing could cheer you up?		
Life satisfaction: a sense of contentment, peace, and satisfaction from small discrepancies between wants and needs with accomplishments and attainments.	**Personal growth**: have feelings of continued development and potential and am open to new experience; feel increasingly knowledgeable and effective.	**Social actualization**: care about and believe society is evolving positively; think society has potential to grow positively; think self-society is realizing potential.
• During the past 30 days, how much of the time did you feel satisfied; full of life? • Overall these days, how satisfied are you with your life? (0–10, where 0 = terrible and 10 = delighted) • Satisfaction may be measured in life domains such as work, home, neighborhood, health, intimacy, finances, parenting.	• For me, life has been a continuous process of learning, changing, and growth. • I think it is important to have new experiences that challenge how I think about myself and the world. • I gave up trying to make big improvements/changes in my life a long time ago. (–)	• The world is becoming a better place for everyone. • Society has stopped making progress. (–) • Society hasn't improved for people like me. (–)
Happiness: having a general feeling and experience of pleasure, contentment, and joy.	**Purpose in life**: have goals and a sense of direction in life; past life is meaningful; hold beliefs that give purpose to life.	**Social contribution**: feel I have something valuable to give to society; think daily activities are valued by the community.
• Overall these days how happy are you with your life? • How frequently have you felt (joy, pleasure, happiness) in the past week, month, or year?	• Some people wander aimlessly through life, but I am not one of them. • I live life one day at a time and don't really think about the future. (–) • I sometimes feel as if I've done all there is to do in life. (–)	• I have something valuable to give to the world. • My daily activities do not create anything worthwhile for my community. (–) • I have nothing important to contribute to society. (–)
	Environmental Mastery: feel competent and able to manage a complex environment; choose or create personally suitable community.	**Social Coherence**: see a social world that is intelligible, logical, and predictable; care about and am interested in society and contexts.
	• The demands of everyday life often get me down. (–) • In general, I feel I am in charge of the situation in which I live. • I am good at managing the responsibilities of daily life.	• The world is too complex for me. (–) • I cannot make sense of what's going on in the world. (–) • I find it easy to predict what will happen next in society.

Table 1 Continued

Hedonia *Emotional well-being*	*Eudaimonia* *Psychological well-being*	*Eudaimonia* *Social well-being*
	Autonomy: am self-determining, independent, and regulate internally; resist social pressures to think and act in certain ways; evaluate self by personal standards.	**Social integration**: feel part of community; think I belong, feel supported, and share commonalities with community.
	• I tend to be influenced by people with strong opinions. (−) • I have confidence in my own opinions, even if they are different from the way most other people think. • I judge myself by what I think is important, not by the values of what others think is important.	• I don't feel I belong to anything I'd call a community. (−) • I feel close to other people in my community. • My community is a source of comfort.
	Positive relations with others: have warm, satisfying, trusting relationships; am concerned about others' welfare; capable of strong empathy, affection, and intimacy; understand give and take of human relationships.	
	• Maintaining close relationships has been difficult and frustrating for me. (−) • People would describe me as a giving person, willing to share my time with others. • I have not experienced many warm and trusting relationships with others. (−)	

A negative sign in parenthesis indicates that the item is reverse scored. Response options range from strongly disagree (1), moderately disagree (2), or slightly disagree (3) to neither agree nor disagree (4), slightly agree (5), moderately agree (6), to strongly agree (7).

Social Well-Being Still, there is more to subjective well-being than emotional and psychological well-being. Keyes has asserted that positive functioning includes social challenges and tasks and proposed five dimensions of social well-being. Whereas psychological well-being (and its component, positive relations with others) represents more private and personal criteria for evaluation of one's functioning, social well-being epitomizes the more public and societal criteria whereby people evaluate their functioning in life. These societal dimensions consist of social coherence, social actualization, social integration, social acceptance, and social contribution. Conceptual definitions and representative items are shown in **Table 1**.

Social integration is the evaluation of the quality of one's relationship to society and community. Integration is therefore the extent to which people feel they have something in common with others who constitute their social reality (e.g., their neighborhood), as well as the degree to which they feel that they belong to their communities and society. Social contribution is the evaluation of one's value to society. It includes the belief that one is a vital member of society, with something of value to give to the world. Social coherence is the perception of the quality, organization, and machinations of society, and it includes a concern for knowing about the world. Social coherence is the obverse of a sense of meaninglessness and involves appraisals that society is discernable, sensible, and predictable.

Social actualization is the evaluation of the potential and the trajectory of society. This is the belief in the positive evolution of society and the sense that society has potential that is being realized through its institutions and citizens. Social acceptance is the construal of society through the character and qualities of other people in general. Individuals must function in a public arena that consists primarily of strangers. Individuals who illustrate social acceptance trust others, think that others are capable of kindness, and believe that people can be industrious. Socially accepting people hold favorable views of human nature and feel comfortable with others.

The Structure of Subjective Well-Being

Studies using community and nationally representative samples have supported the theory that social and psychological well-being belong to distinct, but correlated, latent factors. Confirmatory factor models have revealed that the proposed five-factor theory of social well-being provides the best fit, and the proposed six-factor theory of psychological well-being is the best-fitting model. Moreover, the factors of social and psychological well-being are mutually distinct. The scales of social and psychological well-being correlate as high as 0.44, and exploratory factor analysis revealed two correlated ($r = 0.34$) factors with the scales of social well-being loading on a separate factor from the items measuring happiness, satisfaction, and the overall scale of psychological well-being.

Factor analysis also reveals that measures of social well-being are distinct from, but correlated with, measures of emotional well-being. Measures of emotional well-being (positive and negative affect, life satisfaction) are factorially distinct from the measures of psychological well-being. In a national sample of youth between the ages of 12 and 18, measures of emotional well-being, psychological well-being, and social well-being were factorially distinct, suggesting that the structure of the varieties of subjective well-being are continuous from youth to old age.

Age and Subjective, Psychological Well-Being

Since the 1950s, gerontological studies employed subjective well-being as a central construct with the aim of characterizing normative and successful modes of aging. This direction was facilitated by Erikson, who provided the first comprehensive theory of development throughout the entire life span. Erikson proposed stages of adult development, characterized by unique life challenges that provide opportunities for growth as well as decline. The study of subjective well-being in gerontology was facilitated by two main instruments: the Life Satisfaction Index (LSI) and the Philadelphia Geriatric Center Morale Scale (PGCMS). Each of these scales was subjected to factor analysis, which revealed positive as well as negative aspects of aging. Overall, this first generation of research on subjective well-being and aging sparked the conceptualization and study of successful aging.

Early theories and models of aging portrayed it as a process of disengagement and decline in cognitive, social, and emotional functioning. Such portrayals of growing old in America reflected the social reality of aging during about the first two-thirds of the twentieth century, during which time many older adults lived in poverty. Up to 1967, about 30% of adults aged 65 or older lived at or below the government's standard of poverty and reported an average of 30 to 40 days of restricted activity due to their health annually. However, contrary to the models of aging as uniform decline, large national studies have shown that advanced age is often associated with the maintenance or the increase in subjective well-being.

A host of theories that build on the paradigm of successful aging have emerged to explain how individuals adapt or compensate for loss at the same time that they resolve new challenges and optimize extant skills. Moreover, the study of life transitions now reveals that many individuals actively shape the meaning of stressful experience, resolve those stressors to their satisfaction, and thereby learn new coping skills and information about their own strengths and abilities.

Cross-Sectional Age Trajectories

Literally all studies that have investigated age differences in psychological, subjective well-being in adulthood employ cross-sectional data. As such, all observed age differences must be interpreted with caution, since cross-sectional age differences are as likely to reflect generational, cohort differences as they are to reflect developmental changes that reflect the process of aging. This is true of the MIDlife in the United States (MIDUS) national study of adults between the ages of 25 and 74, which was conducted in 1995. This cross-sectional study was the first study of its kind to include all measures of subjective well-being so that one could make comparisons of age differences in emotional, psychological, and social well-being.

Research using the MIDUS data has shown a complex pattern of age increments and age decrements in specific facets of each dimension of subjective well-being. **Figures 1A** and **1B** represent the typical pattern observed for the two main components of emotional well-being, i.e., positive affect and negative affect (items for each scale were shown in **Table 1**). The frequency with which individuals experience positive affect is higher among the oldest adults than among the middle-aged or the younger adults. Moreover, the frequency of negative affect decreases with age. Middle-aged adults report less negative affect than the younger adults, while the older adults report less negative affect than the middle-aged adults.

Unlike emotional well-being, the age differences of facets of psychological well-being reveal a mixed

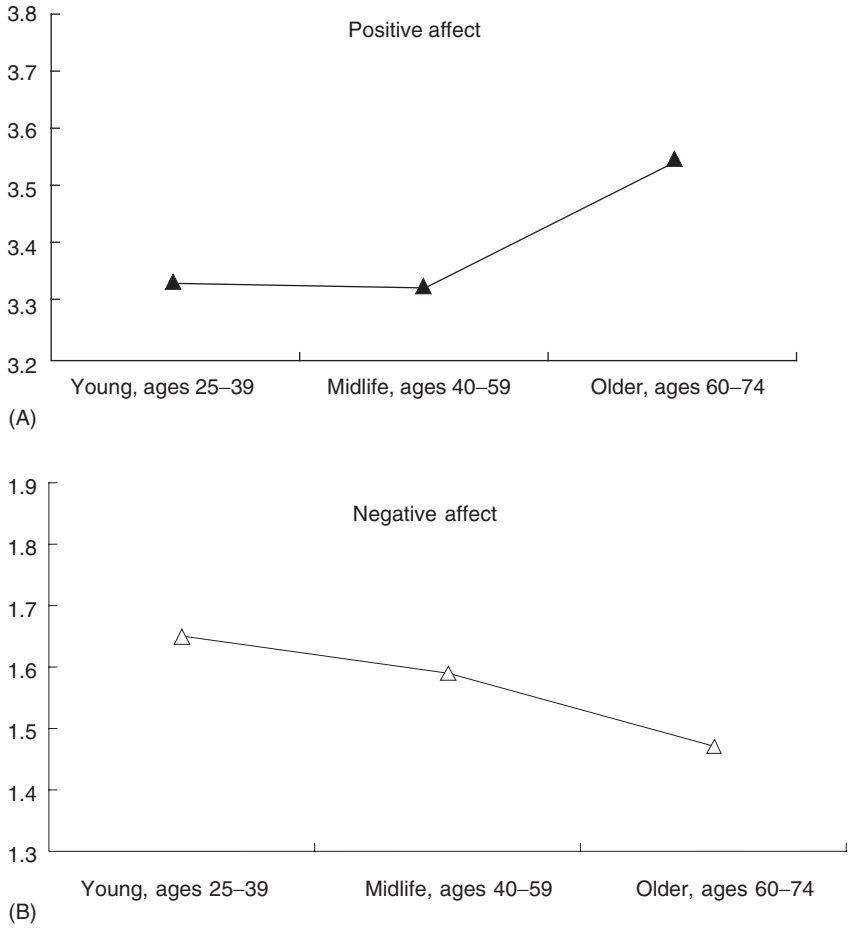

Figure 1 Mean level of positive affect and negative affect scales by age group in the MIDUS national study ($n = 3032$, sample weighted).

pattern of improvement and decline. Using age as a continuous variable, Ryff et al. found age decrements in purpose in life and personal growth. This same pattern is revealed in **Figure 2**, in which age is broken down into age groups of young, midlife, and older adulthood. On the other hand, Ryff et al. found age increments in self acceptance, positive relations with others, environmental mastery, and autonomy. These increments by age are less apparent but still visible in **Figure 2**. These findings coincide, in large part, with three prior studies of psychological well-being summarized by Keyes and Ryff that varied in depth of measurement (i.e., from 20- to 3-item scales), mode of administration (i.e., self-administered and telephone interviews), and sampling technique (i.e., purposive and random national samples). In these prior studies, personal growth and purpose in life declined with age as in the MIDUS study. In the prior studies, environmental mastery and autonomy (autonomy increased in two of the three prior studies) increased with age as in the MIDUS study. In the prior three studies, levels of self-acceptance and positive relations with others remained the same with age, which contrasts with the age increments found in the MIDUS study.

Age variation in social well-being has been studied in two samples – a random sample of adults aged 18 or older residing in Dane County, Wisconsin, and the sample in the MIDUS study. Findings reported in Keyes showed comparable age trajectories in both samples; age was treated as a continuous variable. Social coherence decreased linearly with age. On the other hand, social integration and social acceptance increased linearly with age. Although social actualization and contribution increase with age, the increase decelerates with each added year of life in both studies. That is, the relationship between age and social actualization and social contribution was non-linear, increasing from younger adulthood through middle age, and decreasing from middle age to older adulthood. Findings reported in Keyes coincide with the level of each dimension of social well-being by age group in **Figure 3**. That is, there is a consistent decline in social contribution and social

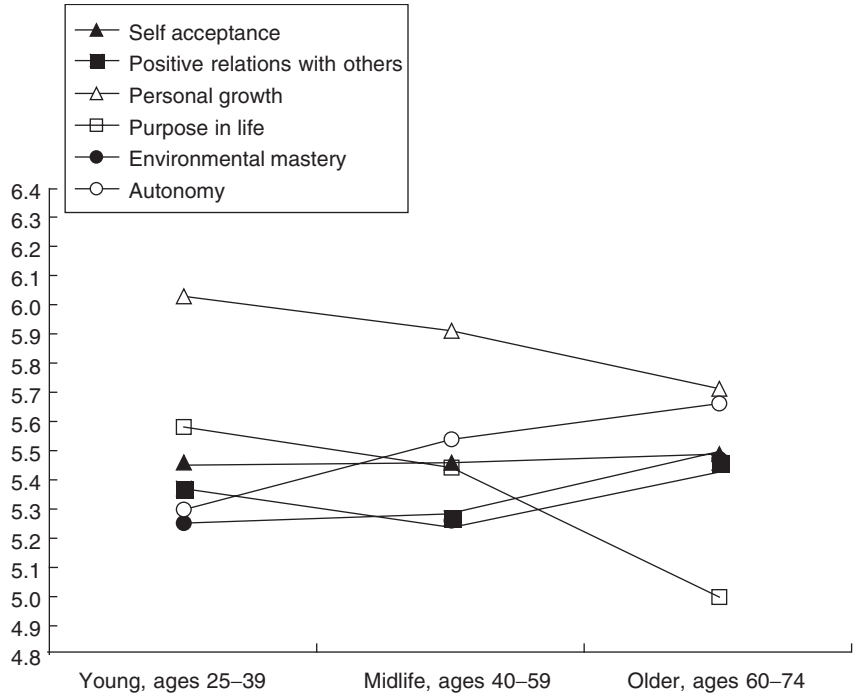

Figure 2 Mean level of Ryff's (1989) three-item psychological well-being scales by age group in the MIDUS national study ($n = 3032$, sampled weighted).

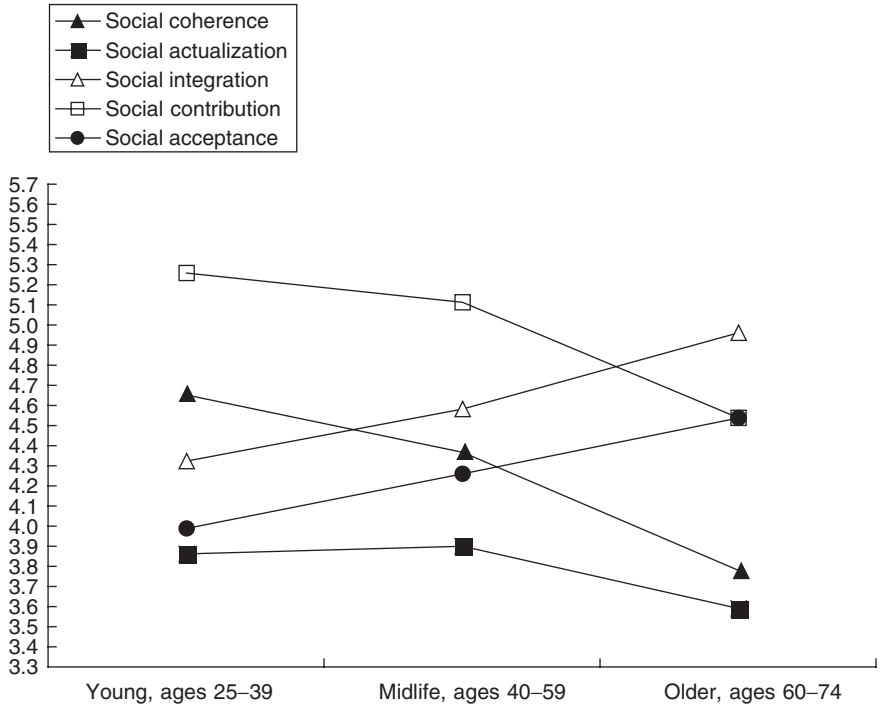

Figure 3 Mean level of Keyes' (1998) three-item social well-being scales by age group in the MIDUS national study ($n = 3032$, sample weighted).

coherence, while there is some suggestion that social actualization increases slightly between young and middle-aged adulthood and then decreases again among older adults. **Figure 3** also reveals consistent age increments in social integration and social acceptance.

Conclusion

In conclusion, psychological well-being is a term used synonymously with subjective well-being and sometimes specifically to refer to a specific kind of subjective well-being. The most inclusive term, subjective well-being, refers to the evaluations and judgments individuals make about the quality of their lives. This domain of gerontological research, sometimes called successful aging because of its focus on positive measures of mental health by age, reveals a diversity of kinds of subjective well-being. A host of studies reveal that subjective well-being consists of two broad traditions that reflect hedonic well-being and eudaimonic well-being. Measures of emotional well-being reflect the hedonic tradition, in which quality of life improves as individuals perceived their lives as more emotionally satisfying. Measures of psychological well-being and social well-being reflect the eudaimonic tradition, in which quality of life improves as individuals see themselves functioning more fully to their potential and capacities.

Overall, research (based primarily on the MIDUS study) suggests that subjective well-being improves between the ages of 25 and 74. Overall, positive affect tends to increase while negative affect tends to decrease with age. Overall, psychological well-being tends to improve with age. Four of the six dimensions of psychological well-being increase with age in the MIDUS study, while personal growth and purpose in life show age decrements. Social well-being, on the other hand, reveals a more balanced profile of age increments (i.e., in social integration and social acceptance) and age decrements (i.e., in social contribution and social coherence), while social actualization is lowest among the young and oldest adults (i.e., it peaks in middle-age).

See also: Life Course; Life Satisfaction; Self Esteem; Social Networks, Support, and Integration.

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R

Reaction Time

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Glossary

Choice Reaction Time – The time between the presentation of one of several stimuli and the occurrence of one of several responses. It is termed choice reaction time because a discrimination has to be made between two or more stimuli and a different response made depending on which stimulus was presented.

Cognition – Mental or intellectual abilities, typically assessed with special psychometric or experimental tests.

Neurological Status – The level of one's health with respect to the central nervous system.

Perceptual Speed – A cognitive ability usually assessed with simple paper-and-pencil tasks requiring search or discrimination tasks.

Slowing – The decrease in speed in many reaction time and perceptual speed tasks associated with increased age.

Speed – The rate at which an individual can carry out many processes. Typically assessed with choice reaction time and perceptual speed tasks.

Introduction

Reaction time is typically measured in terms of the time elapsing between the presentation of a stimulus, which is often a brief visual or auditory signal, and a discrete response such as the press or release of a response key, the initiation of a movement, or the emission of a vocal response.

Historical Background

The first systematic assessment of the relations between adult age and reaction time (RT) was performed by Galton in the late 1800s, although analyses of his data were not published until much later. There were sporadic investigations of the relations between age and RT until about 1950, when interest in this topic increased because of an assumption that an individual's RT might be informative about the status of his or her neurological system. A number of studies then appeared in which RT was the focus of the research.

Beginning in the 1960s, there was an increase in the use of RT as a primary dependent variable because it was assumed to reflect the duration of interesting mental processes. RT measurement in the context of mental chronometry has been a valuable tool in the information-processing perspective on cognition, and a very large number of studies have been reported within this tradition. In recent years a major issue in RT research has been the extent to which RT measures reflect general or specific age-related influences.

Importance

There are three major reasons why RT is an important topic in gerontology. First, the speed with which a simple response can be produced is a very elementary behavioral measure, and therefore may function as a relatively direct indicator of an individual's neurological status. Second, studies of RT have revealed moderately large age relations, and these relations are among the most consistent and robust in all of the behavioral sciences. And third, RT measures have been found to be related to measures of higher cognitive functioning. In fact, measures of speed are actually included in several intelligence test batteries. These three points are elaborated in the following sections.

Indicator of Neurological Status

RT has been considered a reflection of neurological status because a rapid response to an external stimulus not only requires intact sensory and motor processes, but also an efficient system of communication between input and output processes. There are clearly many neurological conditions that could exist

with little effect on RT, but at least at a very gross level it seems reasonable to assume that factors related to intactness of neural connections contribute to the efficiency of responding to environmental stimuli.

Unfortunately, although RT has been assumed to have sensitivity to certain neurological conditions, its specificity is unknown. That is, because all the factors responsible for slowed RT have not yet been identified, slow RT is not necessarily informative about the specific types of neurological impairment that might exist. Among the neurophysiology factors that have been mentioned as possible contributors to age-related slowing are loss of neurons due to vascular complications, reductions in degree of myelination, extent of dendritic branching, or in the quantity of certain neurotransmitters. Until these alternatives can be discriminated, RT may have limited value as an indicator of particular types of neurological impairment.

There is some evidence that age-related slowing is not simply mediated by poorer health because slower RTs with increased age are still evident in samples of adults who report themselves to be in good to excellent health. However, it has been reported that the age-related slowing was greater for individuals reporting incidents of head trauma or general anesthesia, and thus this conclusion should probably be considered tentative until more data are available.

Robustness of Age Relations

In an earlier review of adult age differences in speeded performance, it was found that the median of over 50 correlations between age and a variety of speed measures was 0.45. The magnitude of the relations between age and measures of RT can also be illustrated with results of several recent studies. For example, in a study similar to that of Galton, RTs were obtained from visitors to a public exhibition. In a sample of 2190 adults age 20 and older, simple RT to a single stimulus increased approximately 0.7 ms per year.

Comparisons of simple RT and choice RT are also interesting because the difference between the two times can be interpreted as the time to discriminate between stimuli. That is, choice RT involves a different response for each stimulus, and simple RT consists of the same response to all stimuli, and thus the additional time needed for the choice RT response can be assumed to reflect the duration of the added process. In another study, both simple and choice RT tasks were administered to 1265 adults (833 males, 432 females) between 20 and 90 years of age. The regression equations in this sample indicated an increase of about 0.5 ms per year for simple RT and an increase of about 1.7 ms per year for choice RT. Because the age trends are greater in the measure requiring stimulus discrimination, results such as these suggest that age-related effects on RT are not simply attributable to slower sensorimotor processes.

Age relations have also been investigated in more complex RT tasks. For example, a wide range of tasks can be created in which one response (depression of one key) is made when two stimuli are the same in some dimension, and another response (depression of a different key) is made when the two stimuli are different. To illustrate, in one version of the task the stimuli can be pairs of digits, with the decision based on physical identity, and in another version of the task the stimuli can be pairs of digits and symbols, with the decision based on whether the digit–symbol pair was equivalent according to a code table displayed simultaneously with the stimuli.

Figure 1 illustrates means by decade for these two measures in a sample of 583 males and 776 females, with between 70 and 152 individuals in each decade. Notice that the age trends are monotonic and nearly continuous and that the patterns are nearly identical for males and females. However, the average RTs are greater, and the age-related effects are larger for decisions based on associational equivalence (i.e., digit–symbol) compared to those based on physical identity (i.e., digit–digit). Regression analyses for the physical identity RT measure revealed an increase of approximately 6.4 ms per year, whereas those for the association RT measure had an increase of about 15 ms per year.

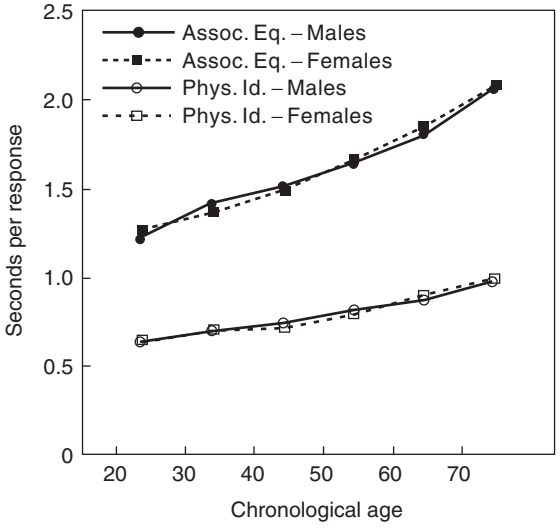

Figure 1 Mean reaction time for physical identity and associational equivalence decisions as a function of age.

The pattern of larger age-related effects on measures in which greater amounts of cognitive processing seem to be required is consistent with a large amount of data in the gerontological literature. That is, when the task is merely to make a predetermined response to a single stimulus the age effects are rather slight (e.g., less than 1 ms per year); when the task requires a choice between different stimuli with a different response to each stimulus, the age effects are somewhat larger (e.g., about 1.5 to 2 ms per year); when the task requires two stimuli to be compared the age effects are larger (e.g., about 6 ms per year); and when stimuli are to be compared on the basis of an association then the age effects are even larger (e.g., about 15 ms year).

Because similar patterns of age relations have been found with other speed measures, such as paper-and-pencil tests merely requiring simple motoric responses (e.g., connecting lines, copying digits) or also requiring cognitive operations (e.g., comparison or substitution), RT measures have been interpreted as reflections or indicators of a more general processing speed construct. Age relations on four paper-and-pencil tests hypothesized to reflect sensorimotor speed (i.e., connecting lines: boxes, or copying digits: digit copying), and perceptual comparison speed (i.e., comparing letters: letter comparison, or comparing patterns: pattern comparison) are illustrated in **Figure 2**. Notice that the age trends are relatively slight (i.e., about 5 ms per year) for the two sensorimotor tasks, but larger (i.e., approximately 20 and 56 ms per year) for the two perceptual comparison tasks.

In addition to similar patterns of age relations, speed measures from paper-and-pencil tasks have also been found to have moderate correlations with RT measures. For example, in two samples of 372 adults, the correlations between the paper-and-pencil Pattern Comparison measure and the digit symbol RT measure were 0.60 and 0.61.

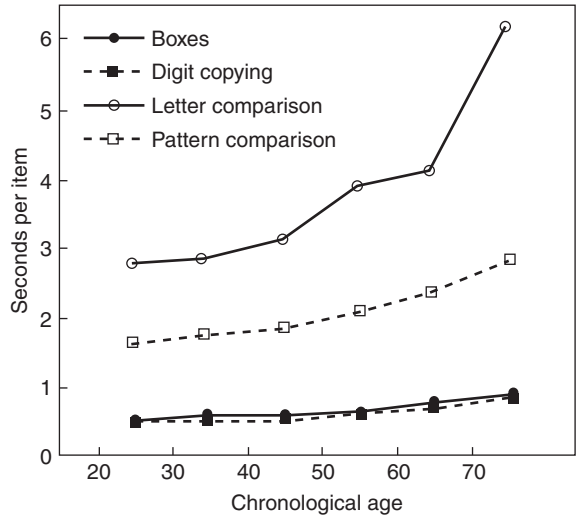

Figure 2 Mean levels of performance in four speeded paper-and-pencil tasks as a function of age.

Relation to Cognition

As noted earlier, speed measures have been incorporated into several widely used cognitive test batteries. The fact that paper-and-pencil speed measures have been found to be moderately correlated with more traditional measures of cognitive functioning indicates that some relation exists between speed and cognition. Moderate relations between RT and paper-and-pencil speed measures and a variety of cognitive measures have also been found in several experimental studies, including some in which the cognitive tests were administered under self-paced conditions with no external time limits.

In several of these studies statistical control analyses have been conducted in which statistical procedures were used to equate people of different ages on an index of speed before examining the relation between age and measures of cognitive functioning. The typical outcome from these analyses has been that the age relations on cognitive functioning are greatly reduced after statistical control of speed. Moreover, with certain combinations of speed and cognitive measures the statistical control procedure has resulted in the complete elimination of the age-related variance in the measure.

Results such as these imply that RT and other speed measures reflect something that is important for the age differences in cognitive functioning. What is not yet obvious is the exact nature of the processes or factors assessed by speed measures that contribute to the age-related variations in cognitive functioning.

See also: Cognitive-Behavioral Interventions; Decision Making and Everyday Problem Solving; Neurotransmitter and Neurotrophic Factors.

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Religion and Spirituality

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Glossary

Extrinsic Religiosity – An instrumental, utilitarian orientation toward religion adopted to provide personal and social well-being; religion used as a means to an end.

Intrinsic Religiosity – An internalized religious orientation in which faith is integrated into beliefs, behaviors, and feelings; religion lived as an end in itself.

Spirituality – A motivational-emotional phenomenon associated with a sense of meaningful integration within the self, with other persons and the world, and with the divine.

Introduction

Once relegated to the margins of gerontology, the study of religion and spirituality now attracts attention from researchers and practitioners representing disciplines that include psychology, sociology, medicine, theology and religious studies, social work, history, literature, the arts, and public policy. The article on religion and spirituality in the first edition of the *Encyclopedia of Gerontology* observed that 'religious gerontology' was emerging in the mid-1990s as a legitimate focus of study for these disciplines, although it also noted that from the 1950s to the 1980s, only a few researchers – primarily sociologists – conducted research on religion and aging. This article begins by examining the current context for thinking about religion, spirituality, and aging, and then reviews major points from the earlier entry in light of recent developments in the field. The article concludes with reflections on themes for scholars and researchers to consider as the baby boom cohort moves into late life.

Contexts for the Study of Religion, Spirituality, and Aging

The life span perspective embraced by most people who study aging processes and older adults emphasizes the ecology of development. This means that gerontologists pay close attention to contextual issues that affect the people they study, the way they formulate their research questions, the methods they employ to gather data, and the conclusions they reach from analyzing the results of the research. The ages of research participants, the shaping events of cohorts' development, and the historical period in which the research is conducted influence the information added to the knowledge stream in gerontology. This is no less true for the study of religion and spirituality than for other topics addressed in this encyclopedia. Therefore, it is important to examine some of the contextual issues that have affected the study of religion and spirituality since the early 1990s. These contexts affect both researchers and the persons who participate in their research.

Some gerontologists, particularly those who conduct qualitative research from a feminist, postmodern perspective (a good example is the work of Janet Ramsey and Rosemary Blieszner), believe it is important to be aware of how the personal perspectives of researchers affect the research enterprise. As author of this article, as well as the previous one, I come to the study of religion and spirituality from the discipline of psychology, particularly the psychology of religion. Psychologists have studied religion

for over a century, although their work has not received wide recognition in the field. Recently, however, this has begun to change, and many of the contextual forces driving increased interest in religion and spirituality among gerontologists are also affecting psychologists. Research on religion and spirituality has become more scientifically rigorous and thus more acceptable in mainstream scholarly journals. The emerging area of 'positive psychology,' which has received widespread attention in the discipline, has created a supportive climate for research on religion and spirituality by emphasizing human strengths, self-transcendence, forgiveness, awe, wonder, gratitude, and hope.

Another influence on the topics reviewed here comes from the fact that my work has been conducted in an environment in which religion, spirituality, and aging are studied primarily from Christian and Jewish perspectives. Although there are some excellent publications on Buddhist, Hindu, and Muslim older persons and the ways their religious beliefs affect various outcomes such as satisfaction with life, the majority of current research publications focuses on participants from either Christian or Jewish denominations, or participants who identify with no religious groups. With the rapid increase in ethnic and religious diversity in the United States, as well as the growth of research on aging in other parts of the world, this situation will undoubtedly soon change, and gerontologists who study religion and spirituality will need to include other world religions in their studies.

Several streams of religious thought and action have converged in the early period of the twenty-first century and have shaped the general intellectual climate, sometimes referred to as the *Zeitgeist*. These include worldwide attention to terrorist groups that claim their actions spring from devotion to religion. Since September 11, 2001, the word 'terrorist' has often been connected with two other words: 'fundamentalist' and 'Muslim.' This has resulted in stereotypes that foster prejudice about all persons who might be called fundamentalists or who embrace the Abrahamic faith tradition of Islam. Another influence on the public's thinking about religion, particularly in the United States, comes from tensions between religion and science, and between religion and politics. This has prompted considerable discussion in academic circles of a wide variety of issues related to how religious faith affects individuals and social groups. However, gaps still exist in scholars' knowledge of religious diversity – gaps sometimes reinforced by social attitudes. For example, the noisy debate about the relation between religion and politics in the United States has solidified stereotypes of evangelicalism and fundamentalism by connecting them with the political category of the 'religious right.' Like all stereotypes, these fail to recognize the diversity and complexity of evangelical and fundamentalist forms of Christianity.

Some of the increased attention to religious topics has resulted from observations of the rapid growth of certain religious groups. Evangelical Christian congregations (often not denominationally affiliated), along with Roman Catholic parishes serving racial and ethnic minority populations, are expanding rapidly, while traditional, 'mainline,' White Protestant congregations are shrinking. Faith communities that are growing often emphasize programs designed to attract families and meet the spiritual needs of children and young adults. In contrast, many religious older people have roots in congregations that are not experiencing this kind of growth. The emphasis on promoting congregational growth by serving younger people can lead to the conclusion that faith communities with high median ages (e.g., those serving mainline Protestants or Jews) are 'dying' and thus a poor 'investment' of religious groups' resources. In other words, ageism can be just as prevalent in religious organizations as in secular settings.

With some exceptions, Christian and Jewish seminaries that educate the next generation of congregational leaders have tended to focus on ways to nurture young families rather than on ministry with aging persons. This situation may be slowly changing, however. With greater recognition of aging demographics, some recent publications have received attention because of their thoughtful treatment of theological and pastoral care issues related to older persons. For example, Stanley Hauerwas – a theologian once described as 'America's leading theologian' by a popular news magazine – has collaborated with several colleagues to edit a book that addresses the theological and ethical challenges to aging Christians in the twenty-first century. Some examples are the tension between secular and religious views of sources of late-life well-being, moral obligations of aging persons, conflicts between capitalist and religious assumptions about dying and death, intergenerational continuity in religious communities, memorial and funeral practices, Christian meanings of suffering, and responses to calls for physician-assisted suicide. A book on Jewish pastoral care edited by Rabbi Dayle Friedman, a leader in seminary training for rabbis working with elders, contains many chapters relevant to work with older persons, including those with dementia. Authors of these chapters wrestle with the nature of healing relationships, pastoral responses to suffering, Jewish understandings of prayer and presence, and Jewish

pastoral care for people who are very ill, dying, or grieving losses.

Prompted in part by greater awareness of the number of people with dementing diseases and the need to provide holistic care that values the personhood of all who suffer from Alzheimer's disease and related dementias, practitioners and researchers are paying attention to their spiritual needs and potential for spiritual growth. Evidence of this can be seen in the second volume of *Aging, Spirituality, and Religion: A Handbook,* which has four chapters entirely devoted to dementia; the first volume had none. The journal *Dementia* devoted an entire issue in 2003 to the subject of spirituality and dementia. Topics covered included effects of personal spirituality on the quality of life of persons in early-stage dementia, experiences of Christian, Jewish, and non-religious spousal caregivers, and approaches to spiritual care of persons with dementia. In addition, Elizabeth MacKinlay, Director of the Centre for Ageing and Pastoral Studies in Australia, has edited several books that address dementia.

MacKinlay's work highlights numerous creative ways of applying the scholarship and research of theologians, ethicists, and social scientists to the design of supportive interactions with older adults. Long interested in late-life depression and the possibility that hope can arise from despair, MacKinlay argues that some persons can be helped by being encouraged to explore their need for ultimate meaning in life. Pastoral caregivers and other practitioners attuned to spiritual needs can assist people in finding ways to experience transcendence of disability and loss. Out of this kind of nurturing relationship, older persons may discover a renewed sense of intimacy with God and other persons. In addition, MacKinlay's research has documented how spiritual reminiscence in small groups can help even those with dementia to discover a deeper sense of life meaning.

Another example of the convergence of research and practice comes from work on caregiving. This has been a topic of great interest to gerontologists for many years and has been the object of considerable research. A number of studies have identified religion as an important variable that buffers caregiver stress, particularly among African Americans who perceive greater rewards from caregiving, in all likelihood because of the comfort they experience in religious practices, including prayer. This research supports the important work of faith communities in providing various forms of help to caregivers such as respite care, support groups, and education about caregiving and the needs of frail elders.

Conducting research on issues related to religion and spirituality has always been challenging because of the complex, multidimensional nature of the subject. The current intellectual climate has added to the challenge, while paradoxically also making it possible for more of this work to be done with scientifically sound methods. For example, having adequate funding and institutional support for their work has meant that researchers can conduct large, national probability studies of diverse samples of older persons. In the United States, numerous private foundations as well as federal agencies like the National Institute on Aging have supported this work, and scholarly journals now publish articles on religion that never would have appeared 20 years ago. On the other hand, some researchers worry that some funding sources may promote religious or political agendas that are incompatible with the pursuit of science. Nevertheless, there have been many important developments in the study of religion, spirituality, and aging in the last decade.

A Decade of Research on Religion, Spirituality, and Aging

Definitions and Measures

The article on religion and spirituality that appeared in 1996 included a lengthy discussion of definitions of religion and spirituality. At the time, scholars and researchers were debating the need to define 'religion' and 'spirituality' as discrete phenomena. The context for this was the commonly noted observation in the 1990s that many people claimed to be spiritual but not religious. Researchers were concerned that standard measures of religious behaviors (such as prayer, reading sacred literature, and worship attendance) and beliefs (in a deity, an afterlife, etc.) would exclude those persons who had preserved a sense of the sacred while rejecting so-called 'organized religion.'

Many writers identified religion with institutions that promoted rigid, dogmatic perspectives on human life, whereas spirituality was viewed as more amenable to individual desires to select beliefs and practices from many faith traditions, or to invent new ones. Debates about definitions permeated the literature for several years, although interestingly, these issues were probably more salient to the young and middle-aged researchers than to their older adult research participants. Several studies found that older people described themselves as religious because of their institutional connections, long-held beliefs, and in some cases ethnic identities; unlike many researchers, they tended to equate being religious with being spiritual.

In 1997, Brian Zinnbauer and his colleagues presented research findings that persuasively showed that these two constructs overlap but are distinct. Titled 'Unfuzzing the fuzzy,' their paper argued that both religiousness and spirituality involve beliefs, feelings, and behaviors associated with a search for the sacred – the human conceptualization of ultimacy that transcends material existence. However, religions go further by defining the sacred realm for communities of believers and providing shared methods of approaching, experiencing, and responding to the sacred.

A year later, Robert Wuthnow reported on his studies of the changing landscape of spirituality and religion in the United States and concluded that some people focus on 'dwelling' within patterned, communal, traditional ways of approaching the sacred, while others emphasize 'seeking' the sacred outside of the boundaries of religious institutions. Wuthnow argued that arguments about the merits of dwelling (religiousness) versus seeking (spirituality) missed the point; he stated that a third focus – practice-oriented spirituality – was needed. This refers to practices that originate within religious institutions and are strengthened as people engage in them privately. This view of spiritual disciplines nurtured within a faith community may turn out to be important for how the baby boom cohort attends to religious and spiritual matters as it moves into later adulthood.

Among the current cohorts of older adults, researchers continue to find high levels of professed religiousness, although it is important to note the many ways this can be measured. The multidimensional nature of being religious is now more widely recognized, and researchers are employing a number of scales to assess various aspects of religiousness. Using more than one scale is necessary because, for example, a scale that assesses aspects of an older person's prayer life would not address that individual's involvement with service activities sponsored by religious organizations. For a long time, it has been recognized that older adults' rates of religious attendance may not necessarily reflect their inner feelings of being religious since physical incapacity might prevent them from getting to worship services. Nevertheless, there continues to be a need for measures of religiousness and spirituality that reflect the life worlds of frail persons and those with dementing illnesses.

Diversity

Women of all ages score significantly higher than men in measures of religiousness. Researchers are now attempting to understand the reasons for this difference, which has been repeatedly observed across many cultures. One study showed that gender alone may not be the significant influence. Rather, norms of masculinity may reduce older men's willingness to engage in private religious devotions. Those with a more feminine outlook on life (e.g., with less emphasis on 'toughness') show more intrinsic religiousness. On the other hand, men with low scores on feminine gender orientation (measured by the well-known Bem Sex Role Inventory) are more likely to take leadership roles within their faith communities when they participate in them.

The question of religious diversity is growing increasingly important, although as stated previously, most of the research on religion, spirituality, and aging has involved participants from Christian and Jewish traditions. Even within those groups, however, it is important to recognize diverse theological and social perspectives. Just separating Protestants from Catholics in the Christian tradition ignores Christians from Eastern Orthodox traditions and overlooks vast differences in theology, polity, and practice both within and between denominations. Among Jewish congregations, variability among practitioners of Orthodox, Conservative, Reformed, and Reconstructionist Judaism is rarely acknowledged. Even within religious groups, older and younger persons may have divergent views on worship, private prayer, sacred literature, and rituals like weddings and funerals. Thus, it is important to understand how historical changes within religious traditions may have affected different cohorts' religious faith and identity. For example, the researcher whose knowledge of Catholicism rests upon assumptions formed post-Vatican II may fail to appreciate the spiritual world occupied by those socialized into the faith before Vatican II.

Diversity in race and ethnicity also affects how religiousness and spirituality are experienced and expressed by older people. Neal Krause, a prolific researcher on this issue, has concluded that people of different races experience the same religion (e.g., Christianity) in very different ways. Compared to White Christians, older African American Christians score higher on various religiosity measures, including worship attendance, service sponsored by the congregation, and prayer. Some research with older Blacks shows that they receive greater health benefits from their religious involvement than Whites. Similarly, a longitudinal follow-up of research on older Mexican American Christians found an association between church attendance and reduced risk of mortality; those who attended church once a week had a 32% reduction compared to those who never attended services. Now researchers need to determine

the reasons for variability in the salutary effect of religious attendance in different racial and ethnic groups. One source of promising suggestions comes from work in the areas of positive psychology and health psychology on cardiovascular health. Some studies suggest that people who attend religious services have less hostility and anger and more optimism and hope. Linda Chatters, another prominent researcher on race and religion, has suggested that for African Americans, religious communities reinforce strong social ties and shared beliefs that promote feelings of hope and optimism. She also notes the prophetic function of religion and the way it has functioned within minority communities to mobilize people's critiques of social oppression.

Sexual orientation represents a category of diversity that was rarely noted in the literature on religion, spirituality, and aging a decade ago. Here is another example of contextual forces influencing research and practice. The twenty-first century opened with considerable ferment within religious groups over homosexuality. The community of lesbian, gay, bisexual, and transgendered (LGBT) persons has been welcomed in some religious communities but has been the object of scorn and rejection from others. In 2003, *Aging and Spirituality*, the newsletter of the Forum on Religion, Spirituality and Aging (a constituent group in the American Society on Aging), was devoted to the theme of 'meeting the spiritual needs of LGBT elders.' The authors urged chaplains to recognize that LGBT elders living in long-term care facilities often fear rejection should their sexual orientation be identified. They also described how long-time members of faith traditions that actively campaign against homosexuality experience abandonment by clergy and fellow congregants. The effects of supportive versus rejecting religious communities on the physical and mental well-being of LGBT elders have not yet received attention from researchers.

Religion and Well-being

In the last 10 years, research on religiousness, spirituality, and health accumulated rapidly. One influence on this growth was the collaboration between the Fetzer Institute, a private philanthropic organization, and the National Institute of Aging to bring together a group of researchers who had been studying religion and aging since the 1980s. In 1999, they defined 12 domains of religiousness and spirituality that are important to health, and they published a collection of instruments to measure these domains: daily spiritual experiences, meaning, values, beliefs, forgiveness, private religious practices, religious/spiritual coping, religious support, religious/spiritual history, commitment, organizational religiousness, and religious preference. This work has been widely acknowledged to have advanced the field by defining the multidimensionality of religiousness and spirituality and by providing researchers with reliable and value instruments to use in studies of health.

Two years later, the *Handbook of Religion and Health* appeared. This comprehensive review of the research literature categorized and reviewed an enormous body of research on religion, mental health, and physical disorders. Although not all of this work specifically addressed issues related to older adults, much of the work cited was from the gerontology literature, and the lead author (Harold Koenig) is widely credited as being one of the first persons to conduct large, well-controlled studies of aging, religion, and health.

In regard to mental health, the handbook showed that across the adult life span, religious beliefs and practices are associated with greater well-being, hope, optimism, purpose and meaning, self-esteem, adaptation to bereavement, and social support, and less loneliness, depression, suicidal behavior, anxiety, and alcohol and drug abuse. Marital satisfaction and stability also appear to be higher among more religious persons. Reasons for these associations include the health behaviors favored in some religious traditions, the coping resources offered by religious practices, the social support of faith communities, and the way that religious world views shape the appraisal of stressful life events. The authors took care to note that religion can also have deleterious effects upon people's attempts to cope with life's stressors, and they also reported on studies that showed no associations between religiousness and various mental health measures. However, in general, the message was that religion does have a positive effect on mental health.

The *Handbook of Religion and Health* also reviewed research on many of the serious physical illnesses that afflict older people, including heart disease, hypertension, cardiovascular disease, and cancer. Religious beliefs and practices appear to have a salutary effect on physical health through a multifactorial combination of influences that include encouraging healthy behaviors and discouraging risky behaviors, providing social support systems, and eliciting positive emotional experiences.

Neal Krause has identified six dimensions of religion that may affect health in older persons. As shown in the work on Mexican Americans mentioned earlier, religious attendance is important but very complex to study, as it involves so many different experiences, such as communal singing, silent

prayer, listening to sermons, and having a cup of coffee after worship while chatting with fellow congregants. Prayer has been identified as contributing to health and well-being, although again the picture is complicated by different forms of prayer, beliefs about prayer, physiological responses to prayer, and experiences of connections to others and to God. Prayer represents one form of religious coping, another factor in the relation between religion and health in older people. Encouragement and support for forgiveness by religious communities may alleviate stress and produce positive health outcomes in older adults. Faith communities offer older adults considerable social support that can take many forms, such as public prayers for the sick, inquiries about well-being after a worship service, or a casserole delivered when a person returns from a hospitalization. Finally, Krause notes that religion provides a sense of meaning, which involves not merely an intellectual assessment but also a positive emotional affirmation of life in spite of the suffering and loss of old age.

Across the life course, these dimensions of religiousness can change in significant ways, with some becoming more important and central to a person's life, and others fading in significance. For example, a homebound elder may no longer experience the salutary effects of religious attendance, but may instead develop a more meaningful prayer life. Or prayer may become challenging for the person experiencing dementia, but that individual can still benefit from the loving care and attention of members of the faith community.

Religious and Spiritual Development

The earlier article on religion, spirituality, and aging described a paucity of research on religious and spiritual development in adulthood and a lack of clear answers to the question of whether people become more religious as they grow older. This situation has significantly changed in the last decade with the publication of research using data from longitudinal studies, the development of a validated measure of spiritual life history, investigations of spiritual turning points, and widespread use in congregational and long-term care settings of various approaches to spiritual autobiography.

Paul Wink and Michele Dillon have published a number of papers reporting on their analyses of longitudinal studies of a group of men and women born in the 1920s. This rich source of information about aging and development through the twentieth century has produced several important insights about religious and spiritual development. Wink and Dillon employ Wuthnow's metaphors of 'dwelling' and 'seeking' to describe either people who emphasize traditional religious beliefs as nurtured and supported by religious institutions, or people who focus more on individual quests for connections with the sacred. The participants in this longitudinal study have been interviewed periodically from childhood and adolescence through adulthood, and they have completed numerous psychometric instruments. Wink and Dillon found that the religious lives of the dwellers have been relatively stable, although after midlife, interest in spirituality increased, especially among women. Religious dwellers experienced well-being as a function of their meaningful social interactions and involvements in their communities. People who emphasized seeking also experienced well-being, though this feeling was derived more from individual creative pursuits, acquisition of knowledge, and attention to personal growth.

Another line of research on religious and spiritual development has examined religious trajectories and transitions across the life course. This work employed interviews with older people reflecting on the role of religion in their lives. The authors identified several dimensions of religion that may change as people age: their religious affiliations, the nature and extent of their religious participation, their tolerance for different religious beliefs, their prayer lives, and the salience of religion (experienced in terms of relationship with God, and the balance between certainty and doubt). This research also revealed four different trajectories of religiosity: an increase through adulthood, stability, a decrease, and an ebbing and flowing pattern with religion having greater or lesser significance and influence at different points in adulthood. Finally, the authors identified what they called 'forces' that either increased or decreased religiosity in their participants' lives. Growth in religiosity results from joining a faith community, raising children, having more time for reflection, and experiencing adversity. Reductions in religiosity were associated with children leaving home, disillusionments with religious leaders and institutions, and again, adversity.

Another study on spiritual turning points offers some help in understanding why some people experience an increase in religiosity with adversity and others fall away from their former religious convictions. Interviews with older adults about these turning points found that nearly half occurred during midlife. Most were triggered by loss of some kind. These negative experiences were associated with feeling a loss of control. Some persons had a sense of external control, believing that God was completely in charge of their fates. Others displayed what the authors called 'God-mediated control,' in which

they saw God as a friend or guide with whom they could communicate and from whom they could derive strength and courage. Use of coping strategies that employed this God-mediated sense of control in times of adversity enabled these persons to overcome feelings of helplessness and recover their own sense of personal control.

The data on spiritual turning points were collected as part of a larger study aimed at developing a valid and reliable scale to assess dimensions of an older person's spiritual life history. The research identified four important factors reflecting religious and spiritual experience across a lifetime: lifelong experiences of asking for and receiving help from God, a family history of religiousness, religious social support experienced through adulthood, and the 'cost of religiousness' (problems experienced in religious life such as conflicts within religious organizations). These factors were then examined to see how well they added to explanations of health outcomes based on religious attendance. Only the family history factor failed to be associated with health status (though it significantly predicted consistency in religious affiliation through the years). This study is an excellent example of how examination of factors affecting religious and spiritual development through life can provide insights into the reasons why religion seems to be so strongly associated with late-life physical and mental well-being.

In addition to research on older adults' religious and spiritual development, programs have appeared in recent years to encourage older people to conduct their own spiritual life reviews (sometimes called spiritual autobiographies). Several 'how-to' books have been published for use by individuals and by groups, usually within the setting of a faith community or long-term care facility. David Moberg, a major figure in twentieth-century studies of religion and aging, has suggested that engaging in spiritual life review can help older people to identify their spiritual needs and to evaluate how well they are being met. These needs include meaning and purpose, love and relatedness, forgiveness, spiritual integration, coping with loss, freedom to question, flexibility, preparation for dying and death, being useful, and expressing gratitude. Moberg details several activities that he believes are important for a spiritual life review: listing major turning points in life and reflecting on their spiritual impact, describing religious doubts and fears, identifying blessings, discerning the spiritual meaning of life experiences, rating periods of life in terms of spiritual growth or stasis, and determining a spiritual legacy to be left to others. Moberg urges elders to share their spiritual life reviews with other persons. He believes that through this process, people can discover the possibility of spiritual growth even at a time in life when they feel more like they are shrinking than growing.

Definitive answers to the question of whether adults increase in religiousness and spirituality as they grow older still elude researchers. However, longitudinal studies of religious trajectories, cross-sectional comparisons of religiousness, and retrospective accounts of spiritual life histories all point to the conclusion that most aging persons do experience increased engagement with the search for the sacred, and many call upon the beliefs, rituals, and sacred texts of established religions to support that search.

Researchers now can anticipate working in a kind of natural laboratory as they observe the aging of the baby boom cohort. Many important questions about religion and spirituality have already been posed to members of current cohorts of older people; in 2025, when the oldest members of the baby boom cohort are approaching age 80, we will undoubtedly have a clearer picture of their late-life religious and spiritual development that can be compared with data collected from earlier cohorts and interpreted in the context of well-developed theories of adult development and aging.

Looking Ahead

A number of important new topics have emerged in the literature on religion, spirituality, and aging, and they will undoubtedly be addressed in the next edition of this encyclopedia. These topics include forgiveness, gratitude, prayer, and service to others. In addition, new areas of research and scholarship are just over the horizon, with the merest hints of their existence beginning to seep into some published work. For example, in another decade or so, we may better understand some older adults' desire to become more involved with mystical traditions associated with their religions. Also, discussion about the arts and late-life spirituality is just beginning and will undoubtedly grow in the coming years. The role of faith communities in nurturing religious and spiritual development through involvement with the arts and the practice of meditative disciplines will need to be carefully examined. This work cannot be done solely by social scientists and health researchers; greater participation by scholars with roots in the humanities will be imperative.

A number of behaviors associated with being religious such as forgiving others, expressing gratitude, praying, and offering help should be examined in light of theories about how older adults adapt to

the vicissitudes of aging, regulate emotions, and maintain good social relationships. Instead of merely documenting that older people are more willing than younger adults to forgive others, express more gratitude about the blessings in their lives, pray more often, or show more caring concern for others, researchers in the future will increasingly base hypothesis testing on well-supported psychosocial theories of adult development and aging.

Along the journey of life, many older adults discover that holding grudges, extracting acts of contrition, being bitter, and refusing to forgive or help other people create more stress. Focusing on the positive aspects of life and being grateful for them is an important way in which older adults regulate their emotions. Religious beliefs and acts, supported by participation in faith communities, can offer considerable support and encouragement for living this way. Moreover, when life's 'shipwrecks' come along, older adults are most likely to turn to religious coping, as amply documented in the work of Kenneth Pargament and his colleagues. A major challenge for future researchers will be to assess how the next cohort of elders employs religious resources to cope with the losses and narcissistic insults of aging.

Increasingly, we are viewing older persons as individuals who are actively managing their lives by making choices to optimize well-being and compensate for deficits and losses. Even those with dementia are now being seen in this light despite their very real cognitive challenges. These are robust observations in gerontology and will likely hold up for the next cohort of elders. However, the forms these optimizations and compensations take will likely evolve and change. Aging baby boomers will create their own adaptations to aging; the work reviewed here allows us to predict that many will ground these adaptations in religious beliefs and practices that are supported by participation in faith communities.

Research on older people's religious and spiritual lives in the late twentieth century largely focused on various metrics of well-being, both physical and mental. We now have the well-being question pretty well answered. Good diet, regular exercise, avoidance of harmful substances, maintenance of positive social relationships, control of stress, and experiences of joy and happiness all have been conclusively shown to contribute to late-life well-being. Along the way, researchers showed how all these factors can be connected to certain religious beliefs and practices, although it is also clear that people can experience well-being without being religious.

Perhaps the questions that occupy researchers and scholars in the twenty-first century will not be so concerned with well-being, but, rather, with meaning. Although people will live longer, healthier lives, they will still experience suffering and mortality. Traditionally, people have turned to religious beliefs and faith communities for support and guidance in their efforts to make sense of the contingencies of human life. In the future, practitioners (including clergy), researchers from the behavioral and social sciences, and scholars working in the humanities may take what has already been accomplished in the study of religion, spirituality, and aging and produce a new form of gerontology focused not on well-being, but on meaning. We might call this existential gerontology.

See also: Adaptation; Cultural and Ethnic Influences on Aging; Dementia; Emotions; Ethnicity and Minorities; Life Review; Psychological Well-Being.

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Reminiscence

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Glossary

Guided Autobiography – Facilitated meetings for individuals to produce a record of their lives while exploring the journey with others in a group.

Reminiscence – The process of recalling the past.

Simple Reminiscence – Remembering the past for enjoyment or socializing.

Structured Life Review – A process of reviewing, reorganizing, and reevaluating the overall picture of one's life until it is acceptable to the self.

Introduction

Reminiscence is the process of recalling the past. The memories produce a product: a biography, a story, or a narrative. The product is accessed and reconstructed throughout one's life, and current events continue to color and influence the memory. The topic of remembering the past has captured the imagination of writers for years, but only since the 1960s has the process of reminiscing been seen as a helpful method, rather than as a wandering of the mind.

Since the early 1960s, when a seminal article was written by Butler describing the presence of reminiscing and life review in older people, there has been a proliferation and confusion in the literature regarding reminiscing approaches. Presently there are several approaches falling under the reminiscence paradigm. This article focuses on comparing and contrasting three specific and well-defined approaches to reminiscing: simple reminiscence, guided autobiography, and structured life review. Thus, this article clarifies more than philosophizes.

Three Common Approaches

The following is a general description of each of the three most common reminiscence approaches: simple reminiscing, described by Burnside, Gibson, and Merriam; guided autobiography, based on work published by Birren and Deutchman; and structured life review, according to Haight and Bahr. Though each of these processes uses long-term episodic memories, each approach is a unique and defined method for accessing memory. To clarify and simplify, **Table 1** compares the differences and similarities among the three approaches and presents the separate elements of the three processes under the headings of initial

Table 1 Comparison of three approaches to reminiscence

	Simple reminiscence	*Guided autobiography*	*Structured life review*
Initial purpose			
Purpose	Enjoy, socialize	Adaptation and book	Gain integrity
Components			
Topics	Themes, events	Themes	Developmental
Format	Randomized	Structured	Structured
Participants	One or more	Group	One
Form	Free	Systematic	Systematic
Goals	Directed	Directed	Directed
Literacy	No	Yes	No
Procedures			
Plan	Spontaneous	Planned	Planned
Sessions	One or more	Ten	Eight
Effort	Minimal	Great	Great
Focus	Events	Self	Self/events
Subjects	Specific	Multiple	Life span
Rules	Few	Many	Many
Triggers	Props	Themes	Questions (LREF)
Size	One–six	Five–six	One
Professional	Leader	Facilitator	Listener
Outcomes			
Product	No	Book	No
Results	Therapeutic	Therapeutic	Therapeutic
Life events	Discuss	Accept	Integrate

purpose, components, procedure, and outcomes. Understanding the comparative elements of these three approaches is particularly important for lucid and coherent research. The discussion of each approach follows the differential analysis set out in **Table 1**.

Simple Reminiscing

Simple reminiscing is a broad term, within which all types of recall can occur, but here it is simply remembering the past. Gibson described memory as much more than recall of past stimuli. It involves emotion, will, and creativity in the reconstruction of the past to serve present needs. Burnside described reminiscence as spontaneous and free flowing, occurring in a group or occurring individually when instigated by an event. Simple reminiscence can perhaps be defined as using the past to serve the present.

Initial Purpose The basic purposes of simple reminiscing are usually for enjoying and for socializing. Additional purposes include encouraging informal conversation, promoting emotional and social stimulation, using reminiscence in the assessment process, and creating group cohesion. Bender stressed the importance of defining a purpose before starting any intervention, because in fact the purpose will color the way the intervention is implemented and thus influence the outcomes.

Components The goals for simple reminiscence are simply to get the participants to talk about the past. Common topics that all participants can relate to, such as school years, are chosen to begin the process of reminiscing.

Simple reminiscing can occur individually with one or more persons, but therapeutically simple reminiscing is often conducted in specific groups. Burnside used reminiscing repeatedly as a nursing intervention and noted its acceptance by varied groups of older people. She had great success using reminiscence with groups who had dementia, and she often followed stringent guidelines to implement the intervention she had chosen. There is probably little structure to simple reminiscence, but when occurring in a group the leader ascertains that all participants get a chance to speak and participate. Leaders of reminiscence groups are facilitators, but the inherent expertise in the group lies with the people recounting their personal memories.

Parameters of group work must be respected when conducting a reminiscence group. Because the presence of people recalling memories often stimulates new memories in others, group work lends itself well to reminiscence. As in all groups, the leader should meet individually with potential members to ascertain that they are comfortable participating in such a group and to present the first group topic for their approval. Before the meetings start, the leader must be sure that she or he has located a physical place appropriate for group dynamics, where chairs can be placed in a circle in a relatively quiet atmosphere with few distractions such as loud music or a blaring television. Though the leader chooses the first topic for discussion, the group should pick the future topics. The group can decide on the topics, using props and pictures to stimulate memories. If the group is mixed gender, there should be a division of topics of interest, for example, cars for men and fashions for women. Often it is easier to run a reminiscence group with people who have similar backgrounds and interests. Participants may or may not be literate and educated; all can enjoy the process.

Procedure Simple reminiscence involves certain procedures for implementation. There may be only one reminiscence session, or there can be a series of them.

The act of reminiscing is spontaneous, not methodological work, so there are few rules for participants. Taking part in a reminiscing group is a pleasurable event and requires minimal work from participants. Any cue can instigate the process in one's mind, and when the thoughts are shared there is a transmission of memories to another person who may become excited to divulge similar and spontaneous ideas. The cues may be about past events or specific occasions, not necessarily about the self and the inner self. Sharing memories can create a dialogue and a connection between people.

Memories often involve emotions, and the effective leader of reminiscence must validate the emotional content of the memory as well as the memory itself. The simplest of events can contain hidden trauma in someone's memory. For instance, in a reminiscence/life review workshop, volunteers were invited to share their memories to demonstrate the reminiscence process in groups. A very safe topic was selected: memories of Thanksgiving. Participants spontaneously offered their accounts, except for one young lady not participating even though she had volunteered. When called on, she began to cry as she recounted her husband's early and unexpected death on Thanksgiving day. Her story put an end to the spontaneity and gaiety that had been taking place; the remainder of the time was directed toward putting her back together and continuing the workshop. The mistake was not sharing the topic beforehand. If she

had known the topic, she probably would have refused to engage in the demonstration.

Often memories are triggered by stimuli. A trigger is anything that causes a memory to resurface; it can be a physical prop, a picture, a book, or even an activity such as singing or music. Most triggers are harmless and helpful, especially triggers that are objects that can be touched, smelled, or eaten. Often smell will evoke a long-forgotten memory. Rooms with old-fashioned objects can act as triggers, or an activity from the past, such as cooking, can cause memories to surface. Actually, most fruitful activities with older people in nursing homes are accompanied by reminiscence in some way, even though reminiscence is not the intent. The memories are always present in the subconscious, waiting to surface. When a group of women making bread is kneading dough together, they are generally sharing past experiences from their own kitchens and families.

The time necessary to run a reminiscence group is another part of the process to consider. The reminiscence group can be a one-time affair or can continue each week. It should last for no more than an hour; however, thought must be given to the time involved in getting the participants to and from the group, especially when in a nursing home with participants in wheelchairs. One hour may cover the actual running of the group, but the time commitment on the part of the leader can be much longer.

Six participants who are homogeneous in most ways will make a most successful group. People with hearing and speech difficulties may participate, but getting prostheses, such as the earphones in movie theaters for the hearing impaired, should be planned in advance. The leader must remember that all memories are partial reconstructions, and the veracity of the memory is not as important as the joy found in the telling. For the leader, there is a continuous reward in learning from these living history books.

Outcomes There are numerous outcomes from reminiscing reported in the literature, but most importantly, reminiscence is therapeutic. Many research projects have investigated the effects of reminiscing. Rural-dwelling institutionalized women reported a positive effect on depression. This outcome was particularly important in this community, where there was no available mental health service. In a review of psychological treatments, Kasl-Godley and Gatz found that reminiscence provided people with dementia with interpersonal connections while optimizing their remaining abilities. Puentes used reminiscence with staff to teach therapeutic communication skills.

Guided Autobiography

Guided autobiography offers yet another way to reminisce. Guided autobiography creates an environment that provides the social support and mental stimulation for older adults to review their life stories and share them with others. Writing about one's life is a very powerful form of self-expression while one searches for evidence that his or her life has mattered and has made an impact on the world.

Initial Purpose The initial purpose of a guided autobiography group is to produce a record of one's life while exploring the journey with others in a group. Birren and Deutchman designed guided autobiography to promote successful adaptation to old age and to assist persons in life transitions.

Components Several of the components necessary for writing an autobiography are different from the basic reminiscing components. For example, those who participate in autobiography groups must be literate and able to read and write. They must also be educated enough to enjoy putting their words on paper. The goal of a guided autobiography group is not only self-exploration, but also to produce a book, and there is a structured format in place that helps the writer to achieve this goal. Though this is a systematic group effort, what a participant ends up writing and sharing in class has been edited continuously by the participant her- or himself, between group classes. This process of recalling past events and writing them down provides personal, private thinking time to review the past so that participants can be more thoughtful about what they share in a group.

In guided autobiography, there are specific topics or themes to be addressed at each weekly meeting. Well-designed themes are wonderful bait designed to catch elusive memories and to provide a structure to the whole process of autobiography. There are nine themes presented systematically. Birren described the nine themes as nine prisms reflecting the life story differently, depending on the theme. For example, the first theme is the major branching points in life. The assignment includes probing explanations and questions to help writers gain clarification of their own branching points. A branching point is a life choice; for example, choosing college, getting married, and having children are all significant branching points. Questions that help to clarify the themes such as "What were the events and experiences that had a major impact on the way your life flowed?" help participants to address the themes. The themes themselves prime the pump and spill forth other related

stories, or at least lead to internal thinking about specific events in the past. The themes often cause forgotten emotions to surface as people remember the past. A different theme is addressed at each meeting for nine or ten meetings, sometimes held a week apart or sometimes, in a more intense format, held every other day. Additional themes address family, work, money, health, loves and hates, sexuality, death, and the meaning of life. The autobiographical process is very systematic.

Procedure The procedure for writing an autobiography, while enjoyable, is also work and requires a great deal of effort. The process itself is planned in advance, and anyone who participates must make a personal commitment beforehand because of the time and effort involved. There is a 10-week commitment to recall and examine the participant's life through the themes that serve as the triggers and address multiple life occasions.

Rules govern the way the weekly meeting is run. At the start of each meeting the facilitator presents the theme for the next meeting. At least 30 min is set aside for discussion and clarification of the next theme. After this, refreshments may be served, allowing writers a few minutes to refocus on the theme for the present week. Then the facilitator asks the group for a volunteer to read what they had written during the past week on last week's theme. Each writer can read for 15 min with an additional 5 min set aside for the group to comment and ask questions. The facilitator guides this interchange, particularly at the start of the group's life, when participants are reticent with one another. Over time the group becomes more open and more willing to share personal issues, and often the group will lead itself. By definition, the content is about the self during multiple occasions throughout life.

The autobiography group consists of five to six writers and one facilitator, with each meeting lasting 2 h. This method of recall is systematic and open while being private and spontaneous. When people begin their homework, they are alone at home, giving them private thinking time. By the time they come to a meeting, they have had time to mentally edit their thoughts and can choose to share what they wish, instead of being caught unaware in the presence of others. Though participants write their autobiography, they can choose to read only those parts that they want to share with the group. Once they are within the group, different emotions and thoughts may surface, but if the group has been meeting and sharing for a given amount of time, the group becomes a safe place in which to share troubling thoughts. There is a group effect that occurs in this process. The group can provide immediate and supportive feedback. Individuals in the group can see that their behavior was acceptable because others in the group may describe worse behaviors, thus allowing social acceptance by the group. There is something healing about not being alone, or being not the only one who has had a particularly bad experience. The group process is effective in erasing guilt and shame, which are often the result of harboring secrets over time.

Outcomes Guided autobiography groups apparently are therapeutic, but this is known only from anecdotal evaluations of the groups by the participants and descriptive papers written by the facilitators. There are minimal research projects reporting measured outcomes, yet when people talk about their participation, it is evident that they feel better about themselves and their achievements. The addition of a quantitative evaluation of this group process would support the use of this process more widely.

Structured Life Review

Butler was the first to describe life review as a spontaneous and universal process in which life events were surveyed and reintegrated. He said that as reintegration takes place, people gain new strengths and begin to live life more purposefully. Life review is a process of reviewing, reorganizing, and revaluating the overall picture of one's life until it is acceptable to the self. The structured life review is a time-limited psychosocial intervention specifically designed for older people and readily accepted by them. This process was first established out of a need to structure the life review for research. Over time and through research, the variables that make the process unique and therapeutic were confirmed.

Initial Purpose The initial purpose of the life review is to help the participant reach integrity: a stage of wisdom and peace in which the individual accepts the way his or her life has been lived. Erikson saw integrity as the positive achievement of the eighth stage of life and defined it as accepting the way one's life was lived with no substitutions. The opposite or failure of integrity is depression and despair, a condition common to older people. The past-scanning function of the life review allows people to regain their past while sharing their memories and to view life as a whole.

Components The components of a structured life review are systematic, discrete, and different from other ways of reminiscing. Butler's definition and

Erikson's model form a blueprint for the process and dictate the purpose and goals of a structured life review. For instance, the goal of the life review is to help older people achieve high levels of integrity; this goal is accomplished through a systematic and organized developmental process of reminiscing that covers birth and childhood to the present.

By definition, the life review is structured. The structure of the life span is an integral part of the life review. Structure sometimes feels forced, as the therapeutic listener makes certain the reviewers cover all phases of their lives; however, it is very important to the process. If the intervention was not structured developmentally, reviewers might ignore childhood as unimportant because those memories are so far away. Yet childhood underlies the basis for the rest of the life and may be responsible for issues later in life. Talking about one's childhood often provides great insight. For instance, Haight and Hendrix performed a qualitative analysis of the life reviews of women who were suicidal, comparing them to women who exhibited high life satisfaction. The suicidal women often had lonely, isolated, and unhappy childhoods, resulting in lonely and unhappy girls, who married at a young age to escape from homes where they felt unloved. They then experienced loveless marriages and, since they had never learned to love, did not feel love for their own children. At age 82, while participating in the life review, one woman said, "I was born lonely"; sadly, she would die lonely as well. Structure ensures a complete story, the essence of a life review. People who have not thought of their childhood for years can relive it again. Hence, the structure helps return a sense of self and completeness to the individual.

Structured life review also helps the cognitive process that creates more orderly thinking when problem solving. In many respects, structure serves as retraining; people begin to process their thoughts more clearly. For example, in a project in nursing homes in Northern Ireland, the Mini Mental State Exam (MMSE) was given to a group of women diagnosed with dementia as a way of evaluating the group for baseline cognition. After the structured life review, the MMSE was given again at posttest, resulting in very different and significant gain scores between the group's pretest and posttest ($p < .005$), with the group receiving life review making immense gains. Because it is impossible to change the course of dementia, it was concluded that the structured remembering caused group members to think more efficiently.

The life review is performed on an individual basis. There are only two active people: the reviewer and the therapeutic listener. The therapeutic listener is the person who is conducting the life review and the reviewer is the one recalling the past. A one-to-one interaction is essential for the valuable commitment that occurs during a life review and the therapeutic catharsis that happens. This individual approach results in an intimacy, a significant other for the reviewer, but not a dependency. By doing life reviews on a one-to-one basis, the therapeutic listener provides privacy and acts as a sounding board to reflect the individual's story. Because the listener must be trained in life reviews, he or she can accept the story as it is told, and this in itself builds self-esteem in the reviewer. The reviewer shares innermost thoughts and dark secrets, while the therapeutic listener listens, accepts, and approves so that in the storytelling the reviewer begins to accept him- or herself. With that realization comes a strength that builds self-esteem and independence. The congruence and caring experienced by the reviewer creates a sense of self-worth and makes the therapeutic listener a very significant person to the reviewer. For some reviewers, it may be the first time ever that they have connected with another human being, and that connection is powerful.

People who participate in a life review need not be literate or educated because the questions are asked of them by a trained therapeutic listener. Life reviewers can be healthy and robust, but they may also be frail, ill, at the end of life, and dying. As opposed to both autobiography and reminiscing, life review is performed in private and on an individual basis and thus lends itself to being used with less healthy populations and at the bedside or in a participant's home.

Procedure The procedure that directs a life review is systematically planned. Six to eight 1-h sessions cover the review unless the participant is very old or sick and cannot talk for an hour. If that is the case, the sessions are spread out, but the total amount of time spent reviewing is about 6 to 8 h. The hours are allocated so that the first 2 h are devoted to childhood, family, and home. The second two are devoted to adulthood, and the last two are spent summarizing and evaluating the reviewer's life. When the life review is initially negotiated, the person who is reviewing is given the life review questions and told how the process will be conducted; thus, she or he has full disclosure before agreeing to participate.

The structured life review is guided by questions in a form known as the Life Review and Experiencing Form (LREF), derived from Butler's definition of the life review. These questions are similar to the themes in autobiography in that these questions provide structure, instigate thought, and serve as bait when the participant is fishing for memories. The questions

do not demand an answer but rather serve as probes to help the reviewers explore their lives and perhaps think about things they have not recalled for some time. For example, regarding childhood, the listener might ask whether the reviewer ever felt lonely, who they admired most, if they were ever afraid, or whether they had had enough to eat. When addressing adulthood, the focus is more on jobs, relationships, sexuality, and achievements. Finally, what is called the summary is reached. The summary actually causes an evaluation to take place and includes provocative questions such as "On the whole, what kind of life do you think you've had?" "What was the hardest thing you had to face in your life?" and "What would you change and do over?"

Although these questions are simplistic, what they reveal is often amazing. For example, a Japanese gentleman who had survived the war in Japan and now had dementia was initially totally focused on food. During his life review, he discussed living in the woods, stealing food, and always being hungry. In his dementia, he was continually worried about being hungry, and he began stealing and hoarding food in his daughter's home. During his fourth session, he started to laugh and said it was no wonder he cared about food so much. Surprisingly, he had gained insight into his hoarding behavior, and he became less focused on food and able to enjoy life more.

The amount of time spent in a life review seems essential. The life review process cannot happen in 1 h or in a one-time visit. The relationship between listener and reviewer must build and trust must develop for the therapy to happen. A 6- to 8-week intervention is optimal. In the third week, something happens: people realize what they are doing, and most eagerly embrace the opportunity to continue to disclose, or they may decide against the intervention and ask to drop out. In addition to the time commitment, the life review is work and requires a great effort on the part of the reviewer because it can be so emotional.

The structured life review is of course about the self, and the evaluation of the way a person has lived his or her life is the most important therapeutic factor. The review, reevaluation, and reintegration that take place in a life review allows a person to accept life as it has been lived, resulting in integrity. When a life issue is successfully addressed, the person can put it away and move on with greater energy because the energy is no longer used up in indecisiveness, brooding, or unfinished business. For instance, a review with a 55-year-old depressed woman finally revealed that she thought that the death of her son was her husband's fault. As she talked it through, she determined that he was responsible in one particular way but that there were other factors that contributed to her son's death over which neither she nor her husband had had any control. In the reevaluation, she was able to forgive her husband and move on. The life review helps people finish their business through evaluation. Also, a general freeing of the reviewer's energies allows the reviewer to deal more efficiently with the problems of the present.

Outcomes Life review is therapeutic, as substantiated by outcomes research. Several researchers have noted that the structured life review decreases depression and increases positive psychological outcomes. But research in this area is still minimal because the manualization of the intervention has not reached the sophistication found in other behavioral and psychodynamic approaches, making independent replication difficult. Additionally, much of the research is conducted with small non-randomized samples with no identifiable criteria or diagnoses.

Summary

Simple reminiscence, guided autobiography, and structured life review, three approaches to reminiscence work, offer health providers unique opportunities to serve the general aging population. Defining the purposes before choosing an approach is key to successful reminiscence. An analysis of procedures and components of the processes will clarify the best approach for achieving the desired outcomes.

See also: Life Review; Memory; Narrative and Aging.

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Renal and Urinary Tract Function

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Glossary

Effective Renal Plasma Flow (ERPF) (Para-aminohippuric Acid [PAH] Clearance) – A measure (in ml or cc per minute) of the volume of plasma flowing through the kidney. This can be measured by the para-aminohippuric acid (PAH) or diodrast clearance as low concentrations of these substances are cleared completely by tubular secretion each pass through the kidney. Approximately 92% of plasma perfusing the kidney secretes its PAH into the tubular system so it can be excreted. Renal blood flow (RBF) can be calculated as

$$\mathrm{RBF} = \frac{\mathrm{ERPF} \times \dfrac{100}{92}}{1 - \dfrac{\text{hematocrit}}{100}}$$

The PAH clearance is normally four to five times the glomerular filtration rate.

Glomerular Filtration Rate (GFR) (Inulin or Creatinine Clearance) – A measure (in ml or cc per minute) often corrected to body surface area (meters^2), of the volume of filtrate formed by the kidney glomeruli. The most accurate measure is the inulin clearance, but this requires a constant infusion. Endogenous creatinine clearance provides a much simpler, clinical measure that approximates inulin clearance. The normal value is 100–120 ml per minute; blood urea nitrogen and serum creatinine concentrations begin to increase above normal when this clearance falls below 30 ml per minute.

Urine Osmolality (mOsm/l) (Concentrating and Diluting Ability) – The serum and urine osmolality per kilogram or liter of water is a measure of all solute particles per unit of volume and can be used to measure ability to concentrate urine when water is restricted and to dilute urine when water loaded.

Introduction

Cross-sectional studies of healthy populations show a decrease in kidney function that approximates 1% per year after the age of 40 years, as measured by glomerular filtration rates (inulin or creatinine clearances) and other measures of kidney function that parallel this measure. However, longitudinal studies show there are some elderly individuals who, when followed for periods of up to 20 years, show no decrease. This suggests that loss of renal function is not an inevitable involutional process, but may be the result of pathologic processes in selected individuals. Studies of structural changes with age, on the other hand, demonstrate an increasing prevalence of ischemic obsolescence of glomeruli and glomerulo-sclerosis with age. The ability of the kidney to conserve sodium (salt) and water and an impaired thirst mechanism increases the susceptibility of older individuals to dehydration (hypernatremia). An increased sensitivity to osmotic stimuli with release of antidiuretic hormone increases the

susceptibility to hyponatremia. Kidney and urinary tract diseases are not different in the elderly compared to the young, but frequency and prognosis are altered. Finally, urinary tract dysfunction with age is generally not life-threatening, but does affect quality of life.

Studies in rats have shown the development of proteinuria and impaired renal function during the course of aging associated with significant structural changes in the kidney. The most striking anatomic features are focal and segmental glomerulosclerosis, increases in mesangial matrix, and glomerular and tubular basement membrane thickening. Whether the proteinuria is the cause or an effect of those structural lesions remains unclear; immunological and/or environmental factors may play a prominent role.

In otherwise healthy individuals, the aging kidney also is associated with structural and functional changes. In both cross-sectional and longitudinal studies, mean values of kidney function decrease with age. Results from the Baltimore Longitudinal Study on Aging, however, suggest that the loss of renal function with age is not inevitable and that decreases in mean values may be primarily the result of superimposed pathology (e.g., undetected glomerulonephritis or interstitial nephritis secondary to infections, immunologic insults, drugs, or other toxic exposures; atherosclerotic vascular occlusions with resultant ischemic injury; and urinary tract infections or obstruction). The terms successful and usual aging have been used to distinguish between individuals who age without loss of organ function and the usual cross-section of any aging population where mean values are tabulated. The latter must include individuals with asymptomatic, or at least undocumented, pathology.

A variety of lesions can be observed by the pathologist in patients with impaired renal function. These can be divided into glomerular, tubulointerstitial, and vascular pathologies. For clinical purposes, in this article we have divided the renal disorders into acute renal failure (ARF), nephrotic syndrome, chronic renal failure, and urinary tract infections (UTIs).

Lower urinary tract dysfunction in the elderly, although responsible for a number of medical concerns, is rarely life-threatening with the exception of malignant disease and unrelieved obstruction. These dysfunctions affect quality of life and many require medical management. Urinary incontinence, for example, is one of the most frequent reasons elderly persons are placed in nursing homes. It occurs in more than 50% of nursing home residents. The involuntary loss of urine severe enough to cause social and hygienic problems is seen in 15–30% of community-living elders, especially women. Benign prostatic hypertrophy is another example of a medical concern that develops in virtually all men if they live long enough.

Age-Related Changes in Kidney Structure and Function

Changes in Renal Morphology with Age

Both kidney mass and function decrease after the third or fourth decade of life at the rate of approximately 1% per year so that there is a reduction in renal mass up to 30% by the eighth decade. There is a 30–50% reduction in the number of glomeruli, with a substantial number of the rest developing focal glomerulosclerosis. The number of mesangial cells increases, thereby decreasing the filtering surface while the percentage of epithelial cells decreases, and the mesangium increases from 8 to 12% of the total glomerular volume. Although the number of glomerular tufts per unit area decreases, as does the number of glomerular and tubular cells, the size of surviving cells increases with age. There also is a significant increase in connective tissue in the medulla. Thickening of the glomerular and tubular basement membranes becomes apparent. Finally, diverticula of the distal nephron begin to appear and may be the cause of the cysts frequently seen in the elderly, but not in the young.

The loss of renal mass is principally from the cortex and is primarily vascular in origin, with the most significant changes occurring at the capillary level. Normal aging is associated with sclerotic changes in the walls of the larger renal arteries, but these lesions generally do not encroach on the lumen sufficiently to produce functional changes. Smaller vessels are relatively spared in non-hypertensive elderly subjects with only a small percentage of senescent kidneys showing arteriolar changes. The incidence of sclerotic glomeruli increases with advancing age, from less than 5% of the total glomeruli at 40 years to 10–30% of the total by the eighth decade. One study reported a strong direct correlation between the number of sclerotic glomeruli and the severity of atherosclerotic disease. Furthermore, when the percentage of sclerosed glomeruli was less than 5%, the distribution between cortex and medulla was relatively uniform, but as the percentage increased, the distribution became predominantly cortical.

Several investigators have compared ischemic obsolescence in cortical and juxtamedullary glomeruli. Initially, in both, there is a progressive collapse of the glomerular tuft with wrinkling of the basement membranes, followed by simplification and reduction

in the vascular channels. Hyaline is deposited within both the residual glomerular tuft and the space of Bowman's capsule. Identifiable structures rapidly disappear so that the obsolete glomerulus may be reabsorbed and disappear completely. Reabsorption is suggested by the scantiness of the cellular response and the residual scar. In the cortical glomeruli, there is obliteration of the afferent arterioles with complete atrophy of the glomerular tuft; in the juxtamedullary glomeruli, there is spiraling of the arterioles with subsequent shunting of blood from the afferent to the efferent arterioles. This produces a redistribution of blood flow from the cortical to the juxtamedullary portions of the kidney with age.

Changes in Renal Function with Age

Most data on changes in renal function with age come from cross-sectional studies, because they are easier to perform and can be accomplished over relatively short periods of time. Potential misinterpretations can be introduced by cohort differences and selective mortality, problems that can be avoided only by much more costly, time-consuming, longitudinal studies.

Glomerular Filtration Rate Cross-sectional studies have shown an age-related decrease in renal function after age 30–40 years. Four decades ago, researchers observed a 50% reduction in inulin clearances between 30 and 90 years of age. Data were subsequently collected from 38 studies where individual inulin clearances and ages were recorded and found an accelerating decrease in glomerular filtration rate (GFR) with increasing age in both men (**Figure 1**) and women. The rate of decline was more rapid in men. Rowe and co-investigators, reporting on results from the Baltimore Longitudinal Study on Aging, showed a similar rate of decline in mean creatinine clearances in normal male subjects followed over a 10-year period with clearances obtained every 12 to 18 months.

Although mean true creatinine clearances fell from 140 ml/min/1.73 m^2 between 25 and 34 years of age to 97 ml/min/1.73 m^2 between 75 and 84 years of age, mean serum creatinine concentrations rose insignificantly from 0.81 to 0.84 mg/ml. This shows that mean creatinine production falls at essentially the same rate as mean creatinine clearance, paralleling the decrease in body muscle mass with age. Serum creatinine concentrations in older individuals must be interpreted with this observation in mind when used to determine or modify dosages of drugs cleared totally (e.g., aminoglycoside antibiotics) or partially (e.g., digoxin) by the kidney.

A subsequent report from this study showed that the mean decrease in this volunteer cohort followed over a 23-year period was 0.87 ml/min/year in all subjects and 0.75 ml/min/year in the individuals free of renal and urinary tract disease and not under treatment for hypertension. This is very close to that observed in the above-mentioned cross-sectional analyses. One-third of these subjects, however, had no decline in creatinine clearance, as illustrated by six subjects followed for 15–21 years (**Figure 2**). These observations suggest that the decline in renal function seen with age in cross-sectional analyses is not the result of a universal chronic involutional change, but more likely is a result of intervening pathology in a portion of each population: for example, (1) undetected glomerulonephritis or interstitial nephritis secondary to immunological insults, infections, drugs, and other toxic exposures; (2) vascular occlusions with resultant ischemic injury; and (3) UTIs or obstruction. One of the variables that affects the rate of decline in renal function is blood pressure, as hypertensive individuals exhibit a more rapid decline in renal function when compared to normotensive subjects.

Renal Blood and Plasma Flow The effective renal plasma flow (ERPF), as measured by quantifying para-aminohippuric acid (PAH) clearance, decreases from a mean of 649 ml per min during the fourth

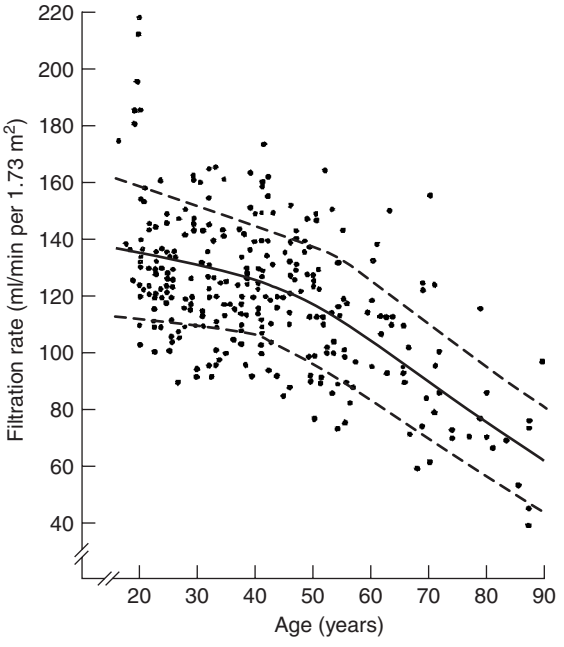

Figure 1 Glomerular filtration rate (inulin clearances) per 1.73 m^2 in normal male volunteers plotted against age from 38 studies. Solid and broken lines represent mean $\pm$ one standard deviation. (Reprinted by permission of Wesson LG Jr., (ed.) (1969) Renal hemodynamics in physiologic states. In: Wesson LG Jr., (ed.) *Physiology of the Human Kidney*, pp. 98–100. New York: Grune and Stratton.)

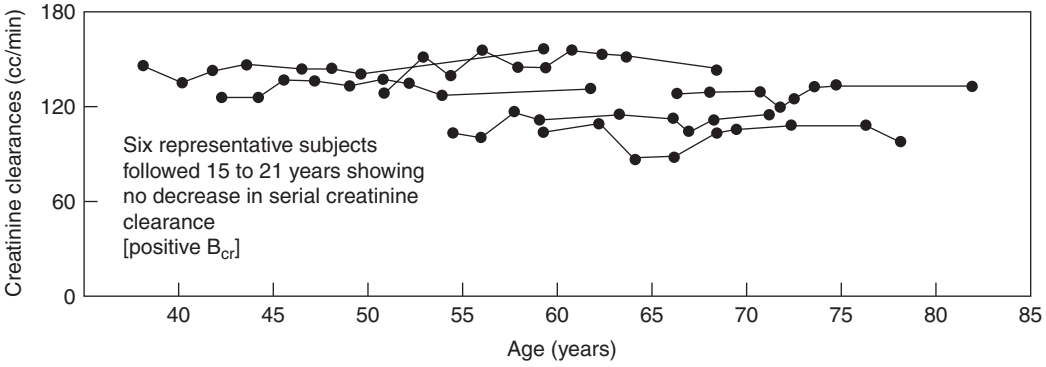

Figure 2 Individual displays of serial creatinine clearances plotted against age in years for six representative subjects from the Baltimore Longitudinal Study of Aging. These six subjects were followed from 15–21 years and showed no decrease in creatinine clearances over this period of time (positive slope of creatinine clearance plotted against time in years). This was representative of the one-third of the 254 normal subjects followed who showed no decline in renal function over the 23 years the study was being conducted. (Reprinted by permission of Lindeman RD, Tobin J, and Shock NW (1985) Longitudinal studies on the rate of decline in renal function with age. *Journal of the American Geriatric Society* 23: 278–285.)

decade to a mean of 289 ml per min during the ninth decade. Since the extraction ratio (ERPF/RPF) at low arterial PAH concentrations is not affected by age (92% in young and old subjects), PAH clearance can be used to reflect changes in renal blood flow with age. The ERPF decreases more rapidly than the GFR, resulting in an increase in the filtration fraction.

The decrease in renal blood flow with age without a parallel decrease in blood pressure could be explained by either the presence of intraluminal vascular pathology (e.g., atheromata or sclerosis) or by increased renal vascular resistance caused by arteriolar vasoconstriction. Two studies have examined this issue, one suggesting that there is a greater resting vasoconstriction in older subjects, and the other suggesting there is a greater resting vasodilation in older subjects. The latter study, using xenon washout techniques, also reported that perfusion of the outer cortical nephrons fell more with age than perfusion of corticomedullary nephrons.

Maximum Tubular Transport Capacity The tubular maximum for PAH secretory transport decreases with age at a rate paralleling the decrease in inulin clearance. The tubular maximum for glucose reabsorption decreases similarly with age. Although reductions in the secretory and reabsorptive tubular maxima with age could be explained by a progressive loss of functioning nephrons, animal studies suggest that tubular cells in old compared to young kidneys have fewer energy-producing mitochondria, lower enzyme concentrations, lower concentrations of total or sodium-potassium-activated adenosine triphosphatase (ATPase), decreased sodium extrusion and oxygen consumption, and decreased tubular transport capacity. Because these studies were performed on tissue slices, it is difficult to be sure that these decreases are not attributable to a higher proportion of non-tubular mass in old compared to young kidneys.

Concentrating and Diluting Abilities A decrease in urine concentrating ability with age is well documented. In the Baltimore Longitudinal Study on Aging, 12 h of water deprivation increased mean urine osmolality to 1109 mOsm/l in young subjects (mean age 33 years), 1051 mOsm/l in middle-aged subjects (mean age 49 years), and 882 mOsm/l in older subjects (mean age 68 years). The decrease in concentrating ability could not be related to an increase in solute load in surviving functioning nephrons, but most likely appears explainable by an increase in medullary blood flow that reduces medullary tonicity due to washout of solute that occurs with age.

Maximum urine osmolality following infusions of large doses of pitressin is decreased in older subjects first undergoing a water diuresis. Elderly subjects, however, respond normally to infusions of pitressin insufficient to maximally concentrate the urine, further supporting the hypothesis that the decrease in concentrating ability observed in older individuals is the result of a decrease in medullary tonicity rather than any defect in the ability of the tubule to respond to antidiuretic hormone.

Maximum diluting ability, as measured by minimum urine osmolality achieved with water loading, also decreases with age. When one compares maximum free water clearance per unit of nephron mass (GFR), there is little difference between young and old individuals, suggesting no basic defect exists in the ability to produce a diluted urine.

Excretion of Acid To maintain systemic acid–base balance, the kidney must excrete a quantity of hydrogen ion equal to that generated by metabolism. Under basal conditions, the blood pH, pCO_2, and bicarbonate of older persons without significant renal disease do not differ from the values observed in young subjects. However, the decreases in blood pH and bicarbonate concentrations following ingestion of an acid load (e.g., 8 g of ammonium chloride) persist longer in elderly persons. The minimum urine pH achieved after an acid load is comparable in young and old individuals. A much larger percentage of the ingested acid load, as measured by total acid excretion (ammonium plus titratable acid minus bicarbonate) is excreted over an 8-h period by the young subjects; however, if total acid excretion is factored by GFR, similar rates of excretion are observed. Young subjects excrete a higher percentage of total acid as ammonium, whereas older subjects have a higher percentage as titratable acid, presumably because they have an increase in urinary buffers per unit of GFR. This limitation in the kidney's ability to excrete acid in older individuals may predispose them to the development of metabolic acidosis and delay their recovery from it.

Glomerular Permeability Functional studies of glomerular permeability show no change with age. Although the incidence of clinical proteinuria increases with age, glomerular permeability to free hemoglobin and a spectrum of different molecular weight dextrans does not differ between young and old subjects. Glomerular basement membrane does thicken with age.

Pathophysiology of the Decrease in Renal Function with Age

Whether the decrease in renal function with age is the result of a progressive involutional process with loss of nephron units and a loss of cellular function similar to the glomerulosclerosis observed in rodents, or is the result of a variety of pathological processes, often undetected, producing acute or chronic damage, or both, remains unresolved. Although results from the Baltimore Longitudinal Study on Aging showed that one-third of the male volunteers (some followed for over 20 years) failed to show any decrease in renal function over the period studied, anatomic studies show a progressive increase in the number of sclerotic glomeruli with advancing age. The former data suggest that there is no inevitable progressive involutional change with age, at least not in all individuals, and support the concept that the decrease in renal function with age observed in cross-sectional studies is the result of superimposed pathology in a portion of the population under study. Anatomic studies, however, suggest there is a sequence of events that results in sclerosis and loss of function in glomeruli that parallels the severity of atherosclerosis elsewhere in the body. An alternative possibility is that as glomeruli become sclerotic, there is a hyperplasia and hypertrophy of cells in remaining glomeruli, perhaps stimulated by circulating growth factors, that compensates and maintains renal function much as observed after unilateral nephrectomy and in diabetes mellitus and hypertension.

A number of examples of undetected pathology causing reduced renal function in the elderly can be cited. For example, one study utilizing scanning techniques to localize defects in kidney function in elderly patients (mean age 75 years) without a history of renal disease found abnormal scans in 25 of 35 (71%) subjects with a mean creatinine clearance of 53 ml/min. Sixteen (46%) showed focal areas of diminished uptake, which were felt to represent ischemic or infarcted areas. Significant pyuria was present in 37% of the patients, and intravenous pyelograms were interpreted as normal in all cases. These findings suggest that vascular occlusions, interstitial infection (pyelonephritis), or both contribute to the decrease in renal function observed in any aging population.

Once a critical level of renal functional deterioration is reached in individuals with kidney injury from any cause, progression of the damage occurs, even if the initiating event or condition is resolved. This is due to a progressive glomerulosclerosis. A vast literature has been generated on the role of hyperperfusion and hyperfiltration in the progression of declining renal function as it has been observed in rodents. It has been hypothesized that high glomerular pressures and plasma flow rates created by high protein intakes contribute to the development of glomerulosclerosis, resulting in a progressive decline in renal function with age alone, as with primary renal disease, renal ablation, diabetes mellitus, and hypertension.

Age-Related Changes in Renal Control of Fluid and Electrolyte Homeostasis

Under normal circumstances, age has little or no effect on serum sodium and potassium concentrations or the ability to maintain normal extracellular fluid volumes. The extrarenal mechanisms responsible for maintaining volume and composition of the extracellular fluids, however, often become impaired in the elderly, especially when stressed by acute and/or chronic illness.

Control of Sodium Balance

Older subjects fail to conserve sodium as efficiently as young subjects when subjected to rigid salt restriction. They have consistently lower plasma renin concentrations and urinary aldosterone excretions on both restricted and unrestricted salt diets and in both supine and upright positions. These decreased plasma renin concentrations and urinary aldosterone excretions in the elderly may be related to the impaired responsiveness to β-adrenergic stimulation observed in the elderly because one of the effects of β-adrenergic stimulation is to increase levels of circulating renin and aldosterone. The decrease in aldosterone at least partially explains the decreased ability of the elderly to conserve sodium when challenged with a low-salt diet.

Two other factors may affect the ability of the elderly to conserve sodium. Circulating atrial natriuretic factor (ANF) levels, although very variable, are increased in the elderly, increasing the salt-losing tendency of the kidney, both directly by its natriuretic effect and indirectly by suppressing renin and aldosterone synthesis and release. Also, as renal function decreases with age, assuming food and salt intake are maintained, the solute load in each residual functional nephron increases, thereby producing a relative osmotic diuresis and a decreased ability to conserve sodium and water.

Control of Potassium Balance

The low renin and aldosterone levels described earlier also could account for the greater tendency of older individuals to develop hyperkalemia when challenged with an increased exogenous (potassium supplements, potassium-containing medications) or endogenous (tissue catabolism, blood in the intestine) load of potassium. Because the distal nephron has such a large capacity for secreting potassium, even in patients with markedly reduced renal function, hyperkalemia generally develops only with one or more additional factors (e.g., excess endogenous or exogenous potassium) or introduction of a drug or disease that affects distal tubular secretion of potassium. Drugs that interfere with this aldosterone-dependent tubular secretion of potassium include the potassium-sparing diuretics (spironolactone, triamterene, amiloride), the β-adrenergic blockers, the angiotensin-converting enzyme (ACE) inhibitors, and the non-steroidal anti-inflammatory drugs (NSAIDs). Elderly persons with a chronic interstitial nephritis, especially diabetics, develop a more pronounced hyporeninemic hypoaldosteronism (type IV renal tubular acidosis) with hyperkalemia.

Susceptibility of Older Individuals to Dehydration (Hypernatremia)

The increased tendency of the older individual to lose both sodium (salt) and water (concentrating defect) contribute to the more rapid development of dehydration and hypernatremia. Another factor that might accelerate the development of dehydration is an impaired secretion of antidiuretic hormone (arginine vasopressin, AVP) associated with the hypoangio-tensinemia (decreased renin-angiotensin-aldosterone) commonly seen in the elderly. This would result in an inability to concentrate the urine and thereby conserve water.

More important, however, is the impairment in the thirst mechanism that develops with age. In one study reported, older subjects following 24 h of water deprivation had increased serum osmolalities and plasma AVP levels and decreased urine osmolalities (concentrations) compared to younger subjects. The younger subjects, however, reported much more thirst, and at the end of the study rapidly drank water to restore plasma osmolality to normal. The older individuals, in contrast, drank little water and still had not corrected the hyperosmolality after 2 h. If older persons had a normal thirst response to water deprivation, the inability to conserve salt and water would be compensated for by an increased fluid intake.

Susceptibility of Older Individuals to the Development of Hyponatremia

Surveys of older individuals in both acute and chronic care facilities show a high incidence of hyponatremia. Chronically hyponatremic individuals show an impaired ability to increase urine volume and decrease urine osmolality when challenged with a water load. The most frequent etiology is a normo-volemic hyponatremia consistent with the syndrome of inappropriate antidiuretic hormone (SIADH) release. Other etiologies included primary salt depletion (hypovolemia), dilutional hyponatremia (hypervolemia, as seen in congestive heart failure (CHF), cirrhosis, nephrotic syndrome) hyperglycemia, and renal failure. In one study of elderly, hospital-acquired hyponatremics, non-osmotic (baroreceptor) stimulation of vasopressin release was a major factor in the development of this electrolyte disorder, regardless of cause. Elderly patients, under a variety of stressors, are much more likely to develop hyponatremia than younger subjects (e.g., postoperatively and following diuretic and sulfonylurea [chlorpropamide] therapy).

Antidiuretic hormone activity in the serum or plasma tends to be higher in older persons when compared to younger persons under comparable

conditions. Following infusions of a standardized hypertonic saline infusion designed to raise serum osmolality to 306 mOsm/l, older subjects had more than a twofold greater rise in serum AVP concentrations. In contrast, ethanol infusions, known to inhibit AVP secretion, produces a more prolonged decrease in serum AVP concentrations in young than in old subjects. These two observations suggest an increasing osmoreceptor sensitivity with age with a greater release of AVP and thus more water retention in response to any given osmotic stimulus. Subsequent studies designed to determine if this was a consistent, age-related increase in vasopressin responsiveness or was specific only for osmotic stimuli showed that older subjects, following periods of quiet standing, failed to increase serum AVP concentrations as much or as consistently as younger subjects. Because these subjects had an intact norepinephrine response to orthostasis, the age-related defect was felt to be distal to the vasomotor center in the afferent limb of the baroreceptor reflex arc. Furthermore, it was suggested that the contrasting influence of age on the vasopressin response to osmolar and volume-pressure stimuli, in at least some elderly, might be related to impaired baroreceptor input to the supraoptic nucleus, which in turn might remove constraints on the response to osmotic stimuli.

Aging and Kidney-Urinary Tract Disease

The inability of the kidney to excrete, through the process of formation of a glomerular filtrate and selective reabsorption and secretion in the tubular system, the normal load of metabolites produced by the body can be separated into ARF or chronic renal failure. When one discusses ARF, and, to a lesser extent chronic renal failure, a further distinction needs to be made between prerenal, renal, and postrenal azotemia. Useful in categorizing these broad groups is calculation of the blood urea nitrogen (BUN)/serum creatinine ratio. With prerenal azotemia, there is either a decrease in renal perfusion (dehydration, hypotension, CHF) or an increase in nitrogen production (bleeding into the gastrointestinal tract) so that the BUN/serum creatinine ratio increases to over 20 to 1. The decreased perfusion associated with prerenal azotemia enhances tubular urea reabsorption disproportionately, raising BUN to serum creatinine concentrations. In one study of ARF in the elderly (>70 years of age), nearly one-half was prerenal in origin (over half of these due to dehydration). The increased hydrostatic pressure transmitted to the tubular fluid in postrenal (obstructive) azotemia also creates a disproportionate reabsorption of urea compared to creatinine increasing the BUN/serum creatinine ratio. These changes are in contrast to azotemia resulting from intrinsic renal disease, where the BUN/serum creatinine ratio ranges between 10 and 14 to 1.

Acute Renal Failure

Of the renal causes of ARF in the elderly, glomerular, tubulointerstitial, or vascular pathology may be causative. The tubulointerstitial nephropathies (acute tubular necrosis [ATN], acute interstitial nephritis [AIN]) are the most common etiologies; the ATN can either be ischemic or nephrotoxic in origin. Most of the acute tubular necrosis of ischemic origin in the elderly is associated with surgical procedures and problems, including pre- and postoperative sepsis. Medical illness such as pneumonia, sepsis, and ischemic heart disease, especially those that produce hypotension, can cause ischemic ATN. Causes of nephrotoxic ATN include the aminoglycoside antibiotics (gentamicin) and intravenous contrast agents used in pyelography, angiography, and computerized tomography (CT). Beside age, factors that increase risk of ATN include diabetes mellitus, preexisting renal insufficiency, multiple myeloma, renal hypoperfusion (dehydration), hypertension, and hepatic disease. A review of prognosis in older patients with this type of ARF suggests age does not appreciably affect survival rates, but older patients need more time to recover renal function and recovered less fully.

Drug-induced AIN has become an increasingly common cause of ARF in the elderly; AIN can also be seen as a complication of infections or systemic disease. Over 40 drugs have been implicated as potential etiologic agents with the penicillins, most commonly methicillin, and NSAIDs being the most frequently incriminated. Patients commonly develop fever, rash, and eosinophilia–eosinophiluria along with non-oliguric, progressive azotemia (*see* Pharmacology).

Acute glomerulonephritis, generally regarded as a cause of ARF in children and young adults, also is more common in the elderly than generally believed. The essential clinical features of hematuria, proteinuria, sodium and fluid retention, decreased renal function, and hypertension are not different in the elderly but are obscured by the presence of preexisting cardiovascular disease and a low index of suspicion. It may be difficult clinically to distinguish patients with poststreptococcal or postinfectious glomerulonephritis from patients with rapidly progressive (crescentic) glomerulonephritis or glomerulonephritis related to systemic disease (lupus erythematosus, vasculitis, subacute bacterial endocarditis, etc.)

Glomerular Disease (Nephrotic Syndrome)

The nephrotic syndrome is defined by the urinary excretion of protein in excess of 3 g per day and other features that are the consequence of this protein loss (e.g., hypoalbuminemia, hyperlipidemia, edema, and a hypercoagulable state). Hypertension and renal insufficiency may or may not be present. The nephrotic syndrome can result from primary glomerular disease, neoplastic disease, or multisystem disease. Studies of nephrotic syndrome in the elderly suggest it is at least as common as it is in younger persons. Several reviews of histologic diagnoses indicate that over one-third of the biopsied patients have a membranous nephropathy with the next most common diagnoses being minimal change disease, primary amyloidosis, mesangial proliferative glomeulonephritis, and focal/segmental glomerulosclerosis. The incidence of membranous nephropathy and amyloidosis was higher than in younger adults, proliferative glomerulonephritis was much lower, whereas minimal change disease was comparable but lower than in children. The incidence of IgA nephropathy and rapidly progressive (crescentic) glomerulonephritis appears to be low in the elderly. Several authors have reported on the increased incidence of underlying malignancies (5–10%) in patients found to have membranous glomerulopathies on biopsy.

Glomerulopathies resulting from systemic disease are more common in the elderly because of the increased incidence of such underlying diseases as diabetes mellitus, amyloidosis (dysproteinemias), vasculitis, and scleroderma. In one review, a secondary cause was found in one-third of the cases. Diabetic nephropathy is the most frequent cause of glomerular disease associated with systemic illness in the elderly (diabetic glomerulosclerosis); however, because many of these patients have an obvious etiology for their nephrotic syndrome, documentation in biopsy series tends to be low and to underestimate the prevalence of this lesion, especially in the elderly. All elderly nephrotics should have urine and serum electrophoreses performed as amyloidosis is the most frequent cause of nephrotic syndrome secondary to systemic disease in biopsied patients.

Chronic Renal Failure

Chronic renal failure results from irreversible damage to both kidneys from a wide variety of glomerular, tubulointerstitial, and vascular causes. Up to 90% of kidney function may be lost without significant morbidity. Progression of the renal lesions can be delayed by managing hypertension, infection, obstructive uropathy, heart failure, and dehydration.

Occlusive arterial disease can cause either acute or chronic renal failure. Bilateral renal artery stenosis due to atherosclerosis may cause, in addition, accelerated hypertension. Renal cholesterol embolization is a geriatric disorder that may occur spontaneously or in association with aortic surgery or angiography in patients with diffuse atherosclerosis. Hypertensives may develop benign or malignant nephrosclerosis. Systemic vasculitis, polycystic renal disease, and scleroderma are other diseases that can cause chronic renal failure without sufficient glomerular disease to cause nephrotic syndrome (*see* Atherosclerosis).

The high frequency of arthritis and arthralgia in the elderly increases the risk of long-term use and abuse of NSAIDs and analgesics. The NSAIDs, because they inhibit vasodilatory prostaglandins, reduce medullary blood flow and inhibit the hexose mono-phosphate shunt that leads to oxidative injury of medullary cells and frequently cause chronic interstitial nephritis and ultimately papillary necrosis. Phenacetin is the most frequently incriminated analgesic, but salicylates and acetaminophen also may be implicated.

Urinary Tract Infections

Pyelonephritis is a serious infection, being the most common cause of Gram-negative bacteremia in elderly hospitalized patients. *Escherichia coli* causes approximately two-thirds of the episodes of infection, with *Klebsiella, Enterobacter, Citrobacter, Enterococcus, Proteus*, and *Pseudomonas* accounting for most of the rest.

Acute symptomatic pyelonephritis often offers a greater diagnostic challenge in elderly than in younger patients, where the classic irritative voiding symptoms make diagnosis readily apparent. Patients with neurological disease (dementia, cerebral vascular disease, parkinsonism) especially have an increased incidence of infection and often present only with altered mental status (somnolence, confusion), tachypnea, loss of appetite, and vague abdominal pains that may suggest pneumonia, diverticulitis, or intestinal obstruction as alternative diagnoses. Fever and leukocytosis may be absent. Pyuria and bacteriuria are seen with both pyelonephritis or infections limited to the lower urinary tract (cystitis) which are common in the elderly, especially women. It is often difficult to determine whether or not infections are limited to the bladder and urethra alone or extend up to involve the kidney. High fever and back (costovertebral angle) pain and tenderness suggest the latter.

Asymptomatic bacteriuria (pyuria and bacteria in the urine greater than 10^5 organisms per milliliter on clean voided examination) is increasingly prevalent

with advancing age, being present in one-third of patients in long-term care facilities. Although these patients with asymptomatic bacteriuria have an increased mortality rate, it remains unclear whether this is an independent risk factor for shortened survival or merely a marker for severe underlying disease. It does not appear that antibiotic therapy has been useful in prolonging survival or preventing recurrent bacteriuria or symptomatic infection, so the prevailing philosophy seems to be to leave asymptomatic bacteriuria untreated until it becomes symptomatic. This also may prevent emergence of resistant organisms.

Lower Urinary Tract Dysfunction with Aging

Effect of Age on the Lower Urinary Tract

Aging affects the lower urinary tract in a number of ways, but incontinence is not a normal consequence. Bladder capacity, the ability to postpone voiding, bladder compliance, and urinary flow rate appear to decline in both sexes, and maximum urethral closure pressure and urethral length appear to decline in women. The number of uninhibited contractions of the detrusor (bladder) probably increases with age, and postvoiding residual volume may increase but probably to no more than 25–50 ml. Although none of these age-related changes causes incontinence, each can predispose one to incontinence, especially because older persons are prone to additional problems that increase the likelihood of this dysfunction.

Transient Incontinence

A number of medical, functional, and cognitive problems superimposed on an elderly person can lead to the development of incontinence. Resnick has used the mnemonic DIAPPERS (with a double P) (**Table 1**) to describe these problems.

Delirium is an acute confusional state, often precipitated by an acute medical problem such as pneumonia or heart failure, that affects one's ability to react appropriately when the bladder becomes distended. UTIs promote a sense of urgency that precipitates voiding. Atrophic vaginitis (urethritis) in elderly women, due to estrogen deficiency, presents with dysuria, dyspareunia, urgency, and incontinence. A number of medications are capable of causing incontinence, most notably those with anticholinergic properties that can impair emptying, especially in those individuals with partial obstruction (e.g., men with benign prostatic hypertrophy). Psychological disturbances, most notably depression, can lead to incontinence. The endocrine causes listed all can cause polyuria, and reduced mobility and stool impaction also can contribute to the development of incontinence. Many times in the elderly, the cause of incontinence is multifactorial, with confusion, medications, and mobility all playing roles (*see* Endocrine Function and Dysfunction).

Table 1 Common causes of transient incontinence

Mnemonic designation	*Cause*
D	Delirium or confusional state
I	Infection, urinary tract
A	Atrophic urethritis or vaginitis
P	Pharmaceuticals (sedative hypnotics, loop diuretics, anticholinergics [antipsychotics, antiarrythmics, antiparkinsonism medications], α-adrenergic agonists and antagonists, calcium channel blockers)
P	Psychological disorders (depression)
E	Endocrine disorders (hypercalcemia, hypokalemia, hyperglycemia)
R	Restricted mobility
S	Stool impaction

Established Incontinence

There are essentially four ways that the lower urinary tract can malfunction to produce incontinence. The detrusor (bladder) muscle either contracts when it should not (detrusor overactivity), leading to urge incontinence, or fails to contract as well as it should (detrusor underactivity), leading to overflow incontinence. Also, outlet resistance can be either persistently high, as seen with obstructive lesions such as prostatism, leading to overflow incontinence, or persistently low, as in the outlet incompetence seen with stress incontinence, usually in women with a history of multiple or difficult deliveries, or men following transurethral resection of the prostate (TURP).

Detrusor overactivity is a condition in which the bladder contracts precipitously with little warning and often empties itself completely. This can occur with normal or impaired contractile function and can result from damage to the central nervous system inhibitory centers (e.g., cerebrovascular accident, Parkinsonism, or Alzheimer's dementia), or it can result from local irritative pathology (e.g., cystitis, bladder carcinoma, or bladder stone) which impairs the ability of the normal brain to inhibit bladder contraction. Both outlet obstruction and outlet incompetence can predispose to detrusor hyperactivity.

Detrusor underactivity can result from damage to the nerves supplying the bladder (disk compression, tumors) or from an autonomic neuropathy (diabetes, alcoholism, pernicious anemia, tabes dorsalis). It can also result from replacement of bladder muscle by

fibrosis and connective tissue, as seen with chronic obstruction (prostatism), whereby the bladder is no longer able to empty normally.

See also: Atherosclerosis; Endocrine Function and Dysfunction; Pharmacology.

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Research Design and Methods

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Glossary

Design – The plan for carrying out a research study. This plan specifies every detail of the study including (but not limited to) what are the variables to be studied and how they are defined and measured; who are the individuals who will be participating in the study; what treatment will be administered to which participants, and how it will be decided which participants receive which treatment; and what statistical analyses are to be used.

Measurement – The procedure by which variables in a study are quantified so that they will be amenable to statistical analysis and in order to form a basis for comparison of results across scientific studies.

Statistical Analysis – A set of procedures by which a researcher uses information gathered from a sample in order to draw more general conclusions applicable to a larger group or population.

Introduction

Science is about studying causes and effects through research design and methods in order to draw conclusions and thereby provide knowledge about the world. When researchers carry out gerontological research, they are trying to establish the causes of certain phenomena that have been observed to be associated with aging. Much of the time it is difficult to determine the independent causes of these phenomena. Possible causal factors such as biological changes, preprogrammed genetic influences, environmental insults including drug and alcohol abuse and workplace exposure, education, and cultural and historical influences not only coexist, but influence each other as well as the aging process.

Disentangling which factors cause the phenomena observed and which merely accompany aging is a difficult task. Sometimes, the factors cannot be disentangled completely. But if the issues surrounding causation are carefully thought out, a researcher can usually carry out a study so as to narrow the list of

alternative possible causes dramatically. This is done by paying careful attention to the design of the study, statistical analysis, and measurement.

Fundamentals of Design for Research on Aging

The Role of Theory

Every scientific study starts with a hypothesis, which is a specific statement about what the scientist expects to find out by conducting the study. In the social sciences in general and in aging research in particular, it is very important that the hypotheses stem directly from a clearly and thoroughly specified theory. The theory must incorporate prior research relevant to the topic of interest, and must make predictions that can be tested in an empirical study.

The Concept of Causation

A great deal has been written about the meaning of causation, what constitutes evidence of causation, and how to infer causation in social science research. Covering this literature thoroughly is well outside the scope of this article. Here we will simply mention several aspects of causation that are important to keep in mind, without claiming to have done justice to this important topic. First, a cause always precedes an effect, even if only instantaneously. An effect never precedes a cause. Second, an effect may have several causes. These causes may each be sufficient but not necessary, as when any one of several causes operating alone can trigger an effect; or they may each be necessary, but each alone is not sufficient, as when several causes occurring together are needed to trigger an effect. Third, manipulation of a cause results in manipulation of the effect. This property of causation is the basis of scientific experimentation.

Subject Sampling

A population is the entire universe of individuals to which a research question or finding pertains. The theory upon which a study's hypotheses are based specifies the population. The population may be the entire human race, or all individuals over the age of 50, or all individuals over the age of 50 with at least a high school education, or any group of people of interest to the researchers. Except for the rare instances where resources and subject availability permit collection of data on the entire population, it is necessary to select a manageably sized subset of individuals from the population who will participate in a study. Sampling is the method by which these individuals are selected.

Once the population has been identified, the next step is to identify a sampling frame. The sampling frame specifies the exact pool from which a study's sample is to be drawn. Although in an ideal study the sampling frame would be identical to the population, in practice this is rare. For example, a sampling frame may be confined to a particular geographic area, or to those who have telephones, or to those who will not be moving during the time period the study is to be conducted. It is important to make every effort to identify a sampling frame that is as close as possible to the population of interest, and to be specific about the differences between the sampling frame and the population so that the implications of these differences for the study's results can be carefully considered. The third step in sampling is to draw a random sample of study participants from the individuals in the sampling frame.

In much research in the social sciences 'convenience' sampling is used. In other words, rather than starting with a defined population, identifying a sampling frame, and then drawing a random sample, researchers use samples of individuals who are available for study participation but are not drawn from a population defined *a priori*. There are many reasons why circumstances force researchers into this less than optimal way of collecting data. In general, although drawing a random sample is unarguably the most scientifically sound approach, it is difficult and expensive, particularly if the study involves much more participation than answering a few questions over the telephone. For these reasons and others, researchers are much more apt to draw a sample from a group made up of individuals who are likely to agree to participate (alumni of the university sponsoring the study, for example) even if the group is not completely representative of the population of interest. This non-random sampling procedure has important implications for the external validity of research, which is discussed below.

Variables

As the name implies, variables are quantities that can vary across the individuals in a study. For example, one variable that appears frequently in aging research is age itself, when the individuals taking part in the study are of different ages. Often the variables in a study can be categorized as independent and dependent variables. In traditional laboratory experimentation, the independent variable is the putatively causal variable manipulated by the experimenter, and it has an effect on the dependent variable. With the

advent of field experimentation and quasi- and nonexperimental designs (see below), variables are often referred to as independent even if their relationship with the dependent variable is only predictive rather than causal *per se*. Sometimes the terms *exogenous* and *endogenous* are used in place of independent and dependent, respectively. These are relative terms; a variable may be independent in one context and dependent in another.

Operational Definitions

An operational definition is an exact description of how a variable is to be defined and measured for the purposes of a study. For example, if a study is to compare middle-aged and older adults, it is necessary to have an operational definition of what range of ages constitutes middle age and what range of ages constitutes older. Whenever a standardized instrument, such as an IQ test, is used, the test score serves as an operational definition of the variable of interest. In the case of IQ tests, the test score is an operational definition of intelligence.

Laboratory Experiments and Control

Causal factors can be isolated most convincingly by means of an experiment. An experiment is distinguished from other types of scientific studies by the use of random assignment to treatment. The logic behind an experiment is to establish groups that on average are identical, and then to expose one or more of the groups to a treatment. Usually one of the groups is left untreated so that it can serve as a baseline or *control* group. If *the groups start out identical* and then a treatment is administered *under carefully controlled conditions,* any differences between the groups that are observed can be attributed to the treatment.

There are two parts of the previous sentence that should be elaborated on. First, how does the researcher ensure that the groups start out identical? This is where random assignment, the distinguishing feature of an experiment, comes in. If a scientist decides randomly which group a participant will be in, then on the average (across many studies) the groups will be comparable. Random assignment can be carried out by tossing a fair coin, rolling a fair die, or using a computer program to generate random numbers for use in assignment. It should be noted that the use of random assignment does not guarantee that comparability has been achieved in any particular study. If it is known that balance on certain subject characteristics is desirable, it is wise to stratify the random assignment accordingly. For example, if gender balance across groups is necessary, the experimenter can conduct random assignment separately for males and females.

Second, what is meant by carefully controlled conditions? This means that when the independent variable is manipulated, *only* the independent variable accounts for differences across groups, rather than any other aspect of the study. For example, suppose a scientist wishes to conduct an experiment to study the effects of a particular drug on cognitive performance in the elderly. In this case the independent variable is drug dosage. Participants are randomly assigned either to a group receiving the drug or to a control group receiving a placebo (inert substance). Thus the independent variable can take on two values, either some prespecified dosage of a drug or no exposure to the drug. The dependent variable is cognitive performance. It is operationally defined as performance on a set of several cognitive tasks.

After the drug dose is administered, the participants are given the cognitive tasks to perform. Now suppose all those who receive the drug are tested in the morning hours and all those who receive the placebo are tested in the late afternoon. Thus the time of day that testing takes place differs substantially between the group receiving the drug and the group receiving the placebo. If the group that receives the drug performs better on the cognitive task, it may be because these subjects were fresher and more energetic than the placebo group rather than because of the effects of the drug. A better approach would be to bring all of the subjects into the laboratory at the same time of day, or to make sure that drug and placebo condition subjects are equally likely to participate in a morning or afternoon session.

Field Research and Quasi-Experiments

Although excellent control can be achieved in the laboratory, it is not a very realistic setting. Sometimes the behavior people exhibit in the laboratory does not generalize very well to the world outside the laboratory. In addition, there are many interesting and important questions that cannot be investigated by means of a laboratory study. Questions about such topics as workplace performance and ability to carry out activities of daily living, as well as many others, can often be addressed most directly by venturing outside the laboratory and observing behavior in its natural setting.

Ideally, field research is experimental, that is, it uses random assignment. These are the conditions under which the strongest conclusions can be drawn from a field study. However, in practice, random assignment often cannot be used in field settings.

More often questions must be addressed by means of a quasi-experiment. The term *quasi-experiment* refers to a study where there are treatment and control groups, but random assignment is not used. There are many problems associated with drawing causal inferences from quasi-experimental studies, all of which stem from the initial non-equivalence of groups. If random assignment is not used, the groups are usually not comparable at the outset. Often the existing differences between the groups provide alternative explanations for any results that are observed. For example, suppose a researcher desires to examine the effects of retirement on health. The independent variable is thus retirement, and it can take on two values: retired or still in the workforce. The dependent variable is health, in this case operationally defined as score on a self-report health questionnaire. The researcher takes a sample of people of retirement age, records who is retired and who is not, and has them complete the self-report questionnaire. Suppose it is found that the retired respondents report, on average, poorer health than the respondents who are still in the workforce. Can it be concluded that retirement causes poorer health? No, there is an important alternative explanation. There may be a tendency for the individuals who are in poorer health to choose to retire, while the healthier individuals stay on the job longer. In other words, retirement does not cause poor health; instead, poor health causes retirement. A more definitive study could be done if individuals would agree to be randomly assigned to retire or to stay in the workforce. This is impractical for obvious reasons. Another, more practical approach would be to start with a group of older adults who are still in the workforce but nearing standard retirement age, and observe them over a period of several years. In this way an important question can be addressed: Is declining health followed by retirement, or is retirement followed by declining health? The answer to this question is necessary but not sufficient to allow an inference about which variable, if either, is causal.

The term *non-experiment* refers to a study where there are not treatment and control groups *per se*; instead, the relations among two or, usually, more variables are passively observed with no direct manipulation of an independent variable. The difference between a quasi-experiment and a non-experiment is a matter of degree rather than kind. The main difference between the two approaches is that a quasi-experiment involves a comparison between clearly defined groups. But in neither case does the experimenter use random assignment, so neither design provides inherently stronger causal inference than the other.

Age, Cohort, and Time

Most behavioral research investigates interindividual differences, or differences between people. In research on aging, as well as in all developmental research, researchers are also interested in investigating intraindividual differences, or change within an individual across time; and interindividual differences in intraindividual differences, or differences between people in the nature and amount of individual change over time. There are three broad classes of predictors of intraindividual change over time: age, cohort, and time. Age refers to each individual's chronological age at each observation; cohort refers to the birth cohort or generation, in a sociological sense, to which an individual belongs; and time refers to the time that an observation is made on an individual. These are not independent, because any two of them determine the third. For example, if the time of measurement and an individual's age are known, that individual's cohort can be determined. (*See* Generational Differences: Age-Period-Cohort.)

For many years there were two primary approaches to studying aging: the cross-sectional design and the longitudinal design. In a cross-sectional design, data are collected on individuals of different ages at a single time. Comparisons are then made across ages. The cross-sectional approach has the advantage of being relatively inexpensive and fast. However, the conclusions about aging that can be drawn from a cross-sectional study are limited. First, the existence of differences across groups defined by age does not necessarily imply that individuals undergo corresponding change as they age. Second, the cross-sectional approach confounds age and cohort. In a cross-sectional study, all of the individuals who are a particular age belong to a particular cohort. It can be argued that any observed age differences are in reality due to cohort membership, and that if individuals from different cohorts were involved the results would be different.

In the longitudinal approach, data are collected on individuals repeatedly across time. Longitudinal studies are more expensive and time-consuming, but this design offers the ability to observe intraindividual growth over time. However, with traditional longitudinal designs only a single cohort is studied. Thus it is impossible to determine whether the results will hold for another cohort.

Somewhat more elaborate versions of these designs have been devised in order to address these concerns. In the cross-sequential design, cross-sectional data are collected in two different years. The first year is a traditional cross-sectional study, where people of several different ages are included in

the sample. In a second year, data are collected on independent samples from the same cohorts (who are now older) and on individuals who are the same age as the participants were in the first year, but are members of different cohorts. This permits the comparison of age differences with several different pairs of cohorts involved. In the cohort-sequential design, a longitudinal study involves several cohorts simultaneously. The data collection is arranged so that data are collected on the same ages in each cohort. This allows the comparison of results across cohorts.

Internal Validity

The internal validity of a study is the confidence with which causation can be attributed to the independent variable and not to some other uncontrolled aspect of the study. A few of the possible threats to the internal validity of aging studies are listed below. This is by no means an exhaustive list.

Testing This can be a problem in longitudinal research if participants are given the same tests or asked to complete the same questionnaires frequently. Scores on tests can go up because of increased familiarity with the test rather than because of any real growth in skill or ability, or participants may become bored or irritated and stop paying attention, leading to a decline in test scores.

Instrumentation If a test or questionnaire has different meanings at different points in time in a longitudinal study, this can pose a threat to internal validity. A frequently occurring example of this is floor and ceiling effects. A floor effect is when a test is not sensitive at the low end of the range, usually because it is too difficult and many individuals in a sample score zero on it. Correspondingly, a ceiling effect is when a test is not sensitive at the high end of the range because it is too easy. In aging studies where decline over time may be of interest, floor effects can create a problem.

Differential Subject Attrition It is almost inevitable in longitudinal studies for some participant dropout to occur. Of course, the investigators should do everything possible to keep this to a minimum. Subject attrition becomes a threat to the internal validity of a study when treatment-group dropouts are a different kind of person than control-group dropouts. For example, suppose a study has taken a random sample of older individuals for a study on the effects of cognitive exercises on memory. Participants are randomly assigned to a treatment group that is taught the exercises or a control group that is not taught any exercises. Suppose the individuals most in need of the memory exercises drop out of the control group, because they know they need help and decide to seek it elsewhere. This would leave only the least impaired individuals in the control group. This pattern of subject dropout can make a treatment look less effective than it really is or even ineffective. Other patterns of subject dropout can make a treatment look more effective than it is in reality.

External Validity

External validity is the extent to which the results of a study can be generalized to a clearly defined and theoretically interesting population. Internal validity is a logical prerequisite for external validity, because if a study has poor internal validity it makes little difference whether or not it is generalizable.

The results obtained from a sample can be generalized to a population with a high degree of confidence when the sample was drawn randomly from the population. Thus studies that use careful subject sampling procedures and enjoy good participant retention have the best external validity. However, many studies in the social sciences use convenience sampling, as described above. When a convenience sample is used, the investigator is in a considerably weaker position with respect to generalizability, because the convenience sample is not a random sample. Non-random subject attrition also has a deleterious effect on external validity, even in the rare cases where it does not affect internal validity. Those who choose to drop out of a study are nearly always different from those who choose to continue. They may be involved in more competing activities, less patient, more transient, lower or higher in socioeconomic status, or different in a wide variety of other ways. When the individuals who drop out of a study are different from those who remain, the remaining sample is no longer a random sample, and the results of the study may not be generalizable to the population from which the researchers originally sampled. Severe non-random subject attrition can even transform a random sample into essentially a convenience sample, with a corresponding reduction in external validity.

A Brief Introduction to Statistics

Descriptive Statistics

Descriptive statistics are numbers used to describe a sample or population. Usually descriptive statistics computed on samples are intended as estimates of the corresponding population quantities, called parameters. One type of descriptive statistic is the

measure of central tendency. There are three measures of central tendency in widespread use: the mean, median, and mode. The mean is what is commonly called the average, computed by summing up all the values of a variable and dividing by the number of individuals. The median is the 50th percentile of the distribution, in other words, the point at which half the distribution is above and half is below. The mode is the most frequently occurring score. Although all three measures of central tendency are used to describe distributions, statistical inference (see below) makes much more extensive use of the mean than either the median or the mode.

Another type of descriptive statistic is the measure of dispersion, which conveys a sense of how much variability there is in a sample or population. The simplest and most intuitively obvious measure of dispersion is the range, commonly computed by subtracting the smallest value occurring in a sample or population from the largest. However, the largest and smallest values in a sample tend to be among the least stable, so the range is itself an unstable measure of dispersion. Statisticians prefer the variance, which for populations is defined as the average squared deviation about the mean. The sample-based estimate of variance is computed slightly differently.

Statistical Inference

Research is conducted on samples so that conclusions can be drawn about populations. In fact, researchers are interested in a sample only as a means to an end. The end is drawing conclusions about the population, which contains all the individuals that are ultimately of interest. If it were possible, researchers would study the entire population. However, constraints imposed by time, money, and subject availability preclude this in most cases, except where resources are extensive or the population is small. The purpose of statistical inference is to provide guidelines to the researcher for drawing inferences about a population based on information gathered from a sample.

For purposes of illustration, suppose researchers are interested in whether 40-year-olds differ from 60-year-olds in performance on a cognitive task. In classical statistical inference, one begins with a null hypothesis and an alternative hypothesis. These hypotheses refer to the population, not to any particular sample. The null hypothesis is a statistical straw man, stating that the mean performance on the cognitive tasks is the same in the two populations. The alternative hypothesis is simply that the null hypothesis is not true, in other words, the two populations have different mean performance on the cognitive task. (When the direction of the difference between groups is not specified, as in this example, the hypothesis is *two-tailed*. When the direction of the difference is specified, the hypothesis is *one-tailed*.)

Suppose data on performance on the cognitive task have been collected on a suitable sample of 40-year-olds and a suitable sample of 60-year-olds. Sample means and the difference between the sample means have been computed. Because sample means are usually not exactly equal to population means, even in a case where the population means are identical, there usually will be a difference between the 40-year-old sample mean and the 60-year-old sample mean, due to chance. Over repeated sampling, relatively small differences will occur frequently, whereas larger differences occur less frequently. The logic of hypothesis testing is as follows.

Assume for the moment that the null hypothesis is true, that is, the means are identical in the 40-year-old and 60-year-old populations. Then ask the question: If the null hypothesis is true, what is the probability of observing a difference between sample means of a magnitude at least as extreme as the one obtained in this study? If a difference between sample means at least as large in absolute magnitude as the one observed in this study occurs very commonly when the null hypothesis is true, then the researcher concludes that there is no basis for rejecting the null hypothesis. However, if results at least as extreme as these are very rare when the null hypothesis is true, then the researcher concludes that the null hypothesis is probably incorrect in this case.

The decision about whether or not to reject the null hypothesis hinges on the answer to the question about the probability of obtaining results at least as extreme as those observed, conditional on the null hypothesis being true. The answer is found by referring to one of the many tabled distributions found in statistics books. Depending on the statistical analysis done, the researcher refers to a *t*, *F*, chi-square, or some other distribution. If the statistical analysis is done by computer, the researcher instead refers to the computed probability conveniently appearing on the output.

It is important to understand that statistical hypothesis testing is a decision accompanied by the risk of making an incorrect decision. When the null hypothesis is in reality true, in a certain proportion of cases extreme results will occur by chance, and the researcher will mistakenly conclude that the null hypothesis is false. Concluding that the null hypothesis

is false when it is in fact true is known as a type I error. On the other hand, when the null hypothesis is in reality false, in a certain proportion of cases results will occur by chance that will lead to the conclusion that the null hypothesis should not be rejected. Concluding that the null hypothesis is true when it is in fact false is known as a type II error.

The type I error rate, designated by the Greek letter α, can be controlled very easily simply by defining what is meant by extreme results. For example, if it is decided ahead of time that the null hypothesis will be rejected only if the probability of results at least as extreme as those obtained is 0.01 or less, then the type I error rate is 0.01. However, all else being equal, any measures taken to reduce the type I error rate will increase the type II error rate, sometimes to unacceptable levels.

Statistical power is an important aspect of research that is often not given sufficient consideration. Statistical power refers to the probability of rejecting the null hypothesis given that it is in fact false. It is 1 minus the type II error rate. Statistical power is a function of three aspects of a study: the type I error rate chosen, the true effect size, and the sample size. All else being equal, larger values of any of these quantities result in an increase in statistical power. In practice, a type I error rate of no larger than 0.05 is considered acceptable in scientific research, and in many cases (although by no means all) the effect size cannot be influenced by the researcher. Thus, in most situations the researcher tries to obtain the largest sample size possible in order to maximize statistical power. Whenever a study concludes that the null hypothesis cannot be rejected, a careful look should be taken at the study's statistical power. If the statistical power is low (i.e., the type II error rate is high), this means that the study was not an adequate test of the hypothesis.

Statistical Procedures

There are many statistical procedures that are used extensively in research on aging, including the following:

1. Independent groups *t*-test: compares means from two independent samples to infer whether the corresponding population means are different.
2. Related groups *t*-test: examines the difference between means from two related samples to infer whether in the population this difference is zero.
3. Analysis of variance (ANOVA): compares means from two or more independent samples to infer whether at least one of the corresponding population means is different from the others. Usually accompanied by further examination of differences between means, by means of either *a priori* or *post hoc* procedures. A factorial ANOVA may involve more than one independent variable, which allows the examination of interactions. An interaction occurs when the effect of one independent variable depends on the level of the other.
4. Analysis of covariance (ANCOVA): an extension of ANOVA that allows a statistical elimination or partialling out of the effects of a variable under certain circumstances.
5. Correlation: estimates the extent of linear relation between two variables.
6. Regression: closely related to correlation. Uses one or more independent or predictor variables to build a linear prediction model for a dependent variable.
7. Contingency table analysis: a broad class of procedures involving categorical variables. These procedures are roughly analogous to *t*-tests, correlation, regression, and ANOVA, but they involve all categorical variables. In this category are procedures such as the chi-square test for independence and log-linear models.
8. Multivariate analysis of variance (MANOVA): An extension of ANOVA for situations where there are many related dependent variables. The procedure finds one or more linear combinations of dependent variables that provide maximum differentiation among groups, subject to the provision that the linear combinations are uncorrelated.
9. Discriminant analysis: Exactly the same as MANOVA, but often treated as if it is different. In discriminant analysis the emphasis is placed on using the dependent variables to predict the category of the independent variable.
10. Canonical correlation: the most general multivariate procedure. Canonical correlation starts with two batteries of variables, and then finds the linear combinations of the variables that produce the largest correlation, subject to the provision that the linear combinations are uncorrelated.
11. Growth curve modeling: A relatively new approach that is likely to become widely used in aging research. In growth curve modeling an individual growth trajectory is fit for each participant in a longitudinal study, allowing examination of individual and group differences in growth.
12. Factor analysis: A general set of procedures for empirically determining whether a large set of manifest variables can be represented by a smaller number of latent variables.
13. Covariance structure modeling: A procedure by which models involving latent variables, including regressions between latent variables, can be estimated and tested.

A Brief Introduction to Measurement

Measurement is a set of rules by which numbers are assigned to objects. In research, the objects are usually research participants, often called subjects. Measurement is something commonly done in everyday life. When one measures his or her height with a yardstick, the yardstick is the set of rules by which a number is assigned to height. In much the same way, an IQ test provides a set of rules for assigning a number to an individual's intelligence, a grade point average provides a set of rules for assigning a number to a person's scholastic achievement, and a questionnaire provides a set of rules for assigning a number to an individual's attitude.

Measurement is one of the most significant challenges facing social science researchers. Unlike research in the natural sciences, where quantities can usually be measured directly with a caliper, scale, and so on, research in the behavioral sciences is faced with measurement of quantities that cannot be seen directly. These quantities are called *constructs*. Constructs such as intelligence, temperament, opinions, cooperativeness, and ability to perform a task must be measured by means of subject self-report, subject test performance, or observations by others. Because of this, extensive work on measurement theory has been done in the behavioral sciences. Measurement theory provides guidelines for evaluating the quality of an approach to measurement, and for how to develop a high-quality measurement instrument.

Measurement Validity

Validity is the most important goal in measurement. It is the extent to which an instrument measures the construct it is intended to measure. This is a broad concept, and there is not one single widely accepted method for determining measurement validity. Instead, there are several aspects of validity that should be addressed. In any particular situation, some aspects of validity will be more relevant than others.

Criterion Validity This is the extent to which an instrument can be demonstrated to be related to a variable that serves as a criterion. There are two types of criterion validity, concurrent and predictive. Concurrent validity is established by demonstrating a relationship with a variable measured at about the same time as the measurement instrument being evaluated. For example, a researcher may wish to establish the validity of a shorter self-administered measure intended to replace a lengthy interview. Concurrent validity can be established by collecting data using the self-administered measure along with the interview data, and then computing the correlation between the two measures. A large correlation is evidence for concurrent validity. Predictive validity is established by demonstrating that the instrument in question is a useful prospective predictor in a longitudinal design.

Content Validity Content validity is the extent to which the items or questions making up a measurement instrument are representative of the construct being measured. Good content validity does not require that the items exhaust every aspect of the construct, but it does require that no important aspect is left out.

Construct Validity This has to do with the extent to which the measure is theoretically meaningful. There are many ways to demonstrate this, with the most appropriate way depending on the research questions of interest. One widely used way of demonstrating construct validity is by means of the multitrait multimethod (MTMM) matrix. This framework involves multiple constructs, or traits, all of which are amenable to measurement by a set of several different methods. For example, sociability, extroversion, and altruism might all be measured by means of a self-report questionnaire, reports of friends, and behavioral observation. Data are collected measuring each of the traits by means of each of the methods, and all possible correlations are computed. If there is good construct validity, it is expected that the correlations between different methods measuring the same trait will be large (this is referred to as *convergent validity*) and that correlations between the same method measuring different traits will be low (this is referred to as *discriminant validity*). Today the MTMM matrix is often analyzed by means of covariance structure modeling.

Measurement Precision

Another very important aspect of measurement is its precision. The various measurement theories in the behavioral sciences offer somewhat different definitions of measurement precision. One of the most widely used measurement theories is classical test theory. It offers a definition of measurement precision known as reliability. A new approach to assessing measurement precision, known as generalizability theory, is beginning to be widely used.

Classical Test Theory and Reliability According to classical test theory, every observed score on a test or measure, denoted X, can be divided up into two

components: a true score, T, and an error component, E.

$$X = T + E \quad [1]$$

There are several important assumptions made. First, this relationship is additive; in other words, X is the sum of $T + E$, it is never the product. Second, T and E are independent of each other. Third, the error component, E, is random, so it is independent of any other measure, any other true score, or any other error component. Fourth, if an individual is measured repeatedly, the true score T is unchanging, but the error component E may change. It follows from these assumptions that the variance of X can be divided into two components: the variance of the true score and the error variance.

$$\sigma_X^2 = \sigma_T^2 + \sigma_E^2 \quad [2]$$

It is important to note that the true score variance can be further divided into valid and invalid variance. Valid variance is variance due to the underlying trait the instrument is intended to measure. Invalid variance is true score variance that is not due to the underlying trait the instrument is intended to measure. Instead, it is due to some other trait or quantity. Thus it is a type of error variance, but it is systematic rather than random error. In some ways the term *true score* is a misnomer, because true scores are not necessarily a true reflection of the construct being measured.

Measurement reliability is defined as the proportion of observed score variance that is made up of true score variance:

$$\frac{\sigma_T^2}{\sigma_X^2} \quad [3]$$

All else being equal, a large reliability is desirable in a measurement instrument. When reliability is large, it means that a relatively small proportion of the observed score variance in an instrument is made up of random error. However, a large reliability does not imply that the instrument is valid. In fact, it is possible for an instrument to have a large, even perfect reliability but zero validity, if the true score variance is made up exclusively of invalid variance. Validity, the proportion of observed score variance made up of *valid* true score variance, cannot exceed reliability.

Methods for Assessing Reliability In most measurement situations only the observed score is known. The true score and the error score are unknown. Thus one cannot directly determine reliability. However, there are several methods for approximating reliability.

Test–retest reliability Test–retest reliability of an instrument is computed by measuring subjects at two distinct occasions on the instrument and then computing the correlation. If the correlation is large, this is considered evidence for good test–retest reliability. However, the test–retest procedure makes the assumption that the construct being measured does not change over time. In life span developmental research, this assumption is usually unwarranted. If the subjects in a study undergo change on the construct at different rates between the first and second occasions, the correlation between the two occasions can be low even if the measurement instrument is highly precise.

Split-half reliability Split-half reliability is computed by administering an instrument at a single occasion, randomly dividing the items into two subsets, and correlating the two subtests. The idea is that if the instrument is highly precise, any two halves should be highly correlated. A problem with the split-half approach is that the assessment of reliability can differ considerably depending on which of the many possible divisions of the items is used.

Cronbach's alpha Cronbach's alpha is a way of assessing reliability by comparing the amount of shared variance, or covariance, among the items making up an instrument to the amount of overall variance. The idea is that if the instrument is reliable, there should be a great deal of covariance among the items relative to the variance. Cronbach's alpha is equivalent to taking the average of all possible split-half reliabilities. Most computer packages for statistics in wide use today can compute Cronbach's alpha. Often it is helpful to examine what the Cronbach's alpha becomes after a particular item is deleted. If Cronbach's alpha goes up considerably upon deletion of an item, the item may not belong in the measure.

Generalizability Theory Generalizability theory focuses on identifying and assessing the effects of various possible sources of error in measurement. According to this approach, each measurement situation involves one or more facets. One facet is usually test or questionnaire items. Other facets may be raters, times, or any of a number of possible aspects of a measurement design. (Although times may be a facet, it is important to note that generalizability theory assumes that the quantity being measured is unchanging.) Usually the items, raters, or times are

sampled from the larger population. For example, a test contains a sample of items, not an exhaustive list of all possible items. Generalizability theory poses the question. How generalizable is the score on the instrument to other samples of items, raters, times, and so on? In order to perform a generalizability study, it is necessary to collect data on the instrument in question. Then ANOVA is used to partition the variance in the instrument into components. Some of the variance is attributable to individual differences among the subjects, whereas other variance is attributable to differences within a facet, such as differences between raters. All else being equal, good generalizability is reflected in a larger proportion of variance due to individual differences between subjects and a smaller proportion due to a facet.

A generalizability analysis can provide a great deal of useful information. Because it partitions error variance, it allows the researcher to study the sources of error in a study. The results of a generalizability study give the researcher the information necessary to decide what to do to reduce error. Often increasing the number of elements of a facet, such as increasing the number of raters or the number of items, can reduce the amount of error. Furthermore, the analysis can help the researcher to assess the costs of reducing the length of an instrument or using fewer raters.

Behavioral Observation

Sometimes asking individuals to report on their own behavior is not desirable or even feasible. For example, very young children are not capable of completing self-report questionnaires or responding to in-depth interview questions. Or, it may be desired to measure certain aspects of interpersonal interactions, such as grandparent–parent discussions about child rearing, as they are taking place so that a sequence of conversational statements and responses can be determined. In these situations and many others data are collected by behavioral observation. Trained observers watch behavior, either as it occurs or recorded on videotape, make judgments about what is going on, and record the instances of whatever behavior is of interest. There are several important procedures to follow when collecting behavioral observations. First, a detailed and explicit system for coding the observed behaviors must be developed and pilot tested before data collection begins. Second, the observers should be thoroughly trained in the behavioral rating system. Third, it is critical to have more than one observer rating behaviors simultaneously. Fourth, where possible the observers should be kept uninformed about the study hypotheses or any expectations the experimenter has about the outcome, so that this information will not bias their interpretation of what they see. (They can be briefed about the study after data collection has been concluded.)

There are several methods used to establish measurement precision of behavioral observation. Often the correlation between raters is called interrater reliability. Technically this quantity is not a reliability, although it may be useful information. When the rating involves choosing among qualitatively different categories, Cohen's kappa is an informative measure of interrater agreement and is recommended over the more commonly used percent agreement. For most research the method of choice for assessing measurement precision of behavioral observations is generalizability theory, because it allows the investigator to distinguish among, and ultimately act upon, different sources of measurement error.

See also: Generational Differences: Age-Period-Cohort.

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Respiratory System

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Glossary

Alveolar Capillary Membrane – The alveolar epithelium, interstitial tissue, and capillary endothelium separating gas in the alveoli from the blood in lung capillaries.

Carbon Dioxide Response Slope – The change in ventilation per minute produced by a change in arterial partial pressure of CO_2.

Functional Residual Capacity (FRC) – The volume of air in the lungs at the end of a normal expiration with the respiratory muscles at rest.

Mucociliary Blanket – Hairy cells with covering mucus that lines the airways of the lungs.

Oxygen Response Slope – The change in ventilation per minute produced by a change in arterial partial pressure of O_2.

Oxygen Saturation – The amount of oxygen combined with hemoglobin as a percent of the maximal amount that can be so combined.

Partial Pressure – The escaping tendencies of dissolved gas in the blood (e.g., pO_2, partial pressure of O_2; pCO_2, partial pressure of CO_2).

Residual Volume (RV) – The volume of air remaining in the lung after a maximal expiration.

Vital Capacity (VC) – The maximal volume of air that can be expired after a maximal inspiration.

Introduction

The function of the respiratory system is gas exchange. It supplies oxygen to the body and removes carbon dioxide by propelling air into and out of the lungs in a controlled manner, keeping the levels of the two gases in the blood within narrow limits. This operation is complicated in humans by the sleep/waking cycle, which alters the activity of the muscles of the chest wall and upper airways; by speech, which involves the use of the respiratory muscles; by eating, because the airways must be protected from the entrance of food particles; and by exercise, because the increased demand for oxygen must be met by muscles, such as the diaphragm and intercostals, which are perched on a platform that moves with the contraction of the arm and leg muscles. All this requires the coordinated activity of many elements so that it is not surprising that there are many causes of respiratory failure, as shown in **Table 1**. Although respiratory failure is increasingly frequent in the elderly, aging per se produces only small changes in respiratory system function. However, the continuous exposure to microorganisms and other noxious elements in the air places the airways and lungs in danger and requires elaborate humoral and cellular mechanisms to defend gas exchange. Decreases in immune function do occur with age. In some cases, in part depending on lifestyle, repeated inflammation and repair of the lungs and the airways lead to remodeling, resulting, depending on the balance of repair and destruction, in the loss or fibrosis of lung tissue. This results in hypoxia with its consequent adverse actions on the neurological and cardiovascular systems.

Normal Operation of the Respiratory System

Breathing is an involuntary act controlled by respiratory neurons in the lower brain stem, primarily the medulla and pons. These neurons are interconnected

Table 1 Causes of respiratory system failure

Functional element	*Disease example*
Central nervous system	
Mind	Severe depression
Brain	Stroke
Spinal cord	Amyotrophic lateral sclerosis
Peripheral nerves	Multiple sclerosis
Chemoreceptors	Congenital hypoventilation syndrome
Electrolyte/acid–base balance	Vomiting
Chest wall	Kyphoscoliosis
Respiratory muscles	
Diaphragm and intercostals	Myopathy
Laryngeal and pharyngeal	Enlarged tonsils
Circulation	
Systemic circulation	Heart failure, pulmonary edema
Pulmonary circulation	Pulmonary hypertension
Lungs	
Upper airways	Laryngeal paralysis
Bronchial tree	Asthma
Alveoli	Emphysema
Extracellular matrix	Idiopathic pulmonary fibrosis

in networks and probably also contain pacemaker neurons. They direct the muscles of the thorax and abdomen to contract and relax, altering the pressure around the lung so that air enters the tracheobronchial tree during inspiration and is expelled during expiration. The incoming air is brought to body temperature and humidified, and particulate matters ($>5\,\mu m$) are removed as air travels down through the nasal and oral cavities and the larynx (the upper airways) and then through the trachea, bronchi, and bronchioles (the lower airways). The lower airways are lined by a mucous layer and cilia (mucociliary blanket), which help to remove particulate matter.

Air makes contact with the blood in microscopic air sacs of the lung called alveoli, where O_2 enters and CO_2 leaves the blood by diffusion. The pumping action of the right ventricle propels blood returning from body organs and tissues through the pulmonary artery and its branches to the capillary bed. The pulmonary veins bring blood enriched in O_2 and with lower levels of CO_2 back to the left side of the heart, where the left ventricle pumps the now arterialized blood to the tissues. Oxygen is carried in the blood mainly in combination with hemoglobin but also as dissolved O_2. Carbon dioxide is carried in the blood mainly in the form of bicarbonate but also as CO_2 in solution.

Sensors in the arterial blood (peripheral chemoreceptors) and in the brain (central chemoreceptors) monitor CO_2 and O_2 levels and send signals to the respiratory neurons in the brain, which activate the respiratory muscles. A decrease in the partial pressure of oxygen (pO_2) or a rise in the partial pressure of carbon dioxide (pCO_2) excites these sensors and in turn increases the activity of brain stem respiratory neurons. Contraction of the respiratory muscles becomes more vigorous and more frequent, thereby increasing ventilation (the volume of air entering and leaving the lung). Neurons in the brain stem also help coordinate the operation of the respiratory and cardiovascular systems so that tissue metabolic requirements are met. Increased metabolism, for example, results in increased ventilation and increased blood flow to the tissues where metabolism is arising. When the respiratory system is healthy, the oxygen supplied at the gas–blood interface in the lung (the alveolar–capillary membrane) maintains pO_2 in the arterial blood at sufficiently high levels (>90 mmHg) so that the hemoglobin is nearly saturated with oxygen. Enough CO_2 is removed so that pCO_2 is kept near 40 mmHg to maintain acid–base balance near normal (as measured by arterial pH, about 7.40).

The deterioration of respiratory function as a result of aging itself, although measurable, is relatively small.

In large part, respiratory function is preserved by a special system that includes reflexes that prevent aspiration of foreign material into the lungs. These include the mucocilary blanket lining the airways, which clears particulate matter from the tracheobronchial tree. In addition, immune cells in the alveoli and lymphatic system of the lung remove microbes and other harmful inhaled matter and help neutralize toxic chemicals released in the lung with age.

Effects of Aging on Lung Function

With aging, there is a significant decrease in the elasticity of the lung. Alveoli widen and the alveolar surface area per unit of lung volume decreases. These structural changes are a consequence of biochemical alterations in the extracellular matrix of connective tissues that surrounds the alveoli and bronchi.

Changes in lung elasticity with age affect lung volumes. When the respiratory muscles are inactive, lung volume is determined by the balance between the tendency of the lung to collapse due to its elasticity and the opposing tendency of the thoracic cage to expand. The resting lung volume, the volume at the end of a normal quiet exhalation, is termed the functional residual capacity (FRC). Because the elasticity of the lung decreases with age more than that of the chest wall, FRC is larger in the elderly than in the young.

Peripheral airways are essentially tethered to the lung parenchyma. Lung tissue pulls outward on the airway walls, and the airways are kept open by the elastic recoil of the attached alveolar walls. The loss of lung elastic recoil with age decreases this tethering effect, resulting in a narrowing of peripheral airways. With narrowing, the resistance of the airways to the flow of air becomes greater. The resistive properties of the airways are commonly assessed from measurements of airflow rates out of the lungs during rapid, forceful expiratory maneuvers. Following a maximum inspiration, the volume exhaled during the first second of a subsequent forced expiratory maneuver is termed the FEV1 (forced expiratory volume in 1 second). The reduction in airway caliber that accompanies the loss of lung elastic recoil with advancing age results in a decline in FEV1 that averages about 30 ml/year from age 25 to 65. FEV1 continues to fall after age 65 but at a somewhat reduced rate of 20 ml/year. The annual rate of decline in FEV1 is considerably accelerated in cigarette smokers.

As lung volume decreases from total lung capacity (TLC) (i.e., the volume of air contained in the lungs at the end of a maximum inspiration) to residual

volume (RV) (i.e., the volume of air remaining in the lungs after a maximum expiratory effort), the airways normally shorten and narrow. Near RV, some airways, particularly those at the lung bases, actually close. With reductions in elastic recoil of the lung with advancing age, airways tend to close at higher and higher lung volumes, trapping alveolar gas behind them and raising residual volume. Also, the vital capacity (VC), the difference between TLC and RV, decreases with age.

Changes in lung elastic properties with advancing age do not occur uniformly in alveoli throughout the lung. This lack of uniformity results in unevenness in the distribution of ventilation, usually without adequate compensatory readjustments in the distribution of pulmonary blood flow. As a result, there is a mismatch in the ratio of ventilation to perfusion in some gas-exchanging areas of the lung, and blood leaving those alveoli may not be fully oxygenated, increasing the gradient between the partial pressure of oxygen in the alveolar air and the arterial blood. Some, but not all, investigations suggest impaired diffusion of gas across the alveolar–capillary membrane with aging, but abnormalities in diffusion probably do not contribute significantly to changes in oxygenation with age. The alveolar–arterial oxygen gradient increases by about 1 mm/year from ages 60 to 75 and then remains virtually constant. Overall, arterial O_2 saturation falls only slightly with age, and there are no significant changes in arterial pCO_2 that can be ascribed to aging alone.

The decrease in the ability of the elderly to achieve levels of exercise as high as those of younger people is largely due to changes in the cardiovascular system and in the fiber composition of skeletal muscles rather than to changes in the elasticity of the respiratory system. Both the maximal heart rate and maximal cardiac output that can be achieved during exercise fall with advancing age. The kinetics of changes in cardiovascular variables and oxygen consumption decline as well. However, the elderly may be able to perform for longer periods of time at a higher percent of maximal oxygen consumption than the young.

Effects of Aging on Respiratory Muscle Function

Changes with age in the respiratory muscles contri bute to decrements in respiratory function. Respiratory muscle strength is weaker in the elderly, reducing the maximal pressures that can be exerted during inspiration and expiration. Maximal inspiratory pressure decreases progressively after age 20, whereas the loss in maximal expiratory pressure accelerates past age 50. These reductions in maximal respiratory pressures correlate with age-related reductions in the strength of other muscles, such as the trunk flexor and the handgrip muscles. Moreover, there is evidence suggesting that the respiratory muscles may be more liable to fatigue in the elderly than in the young.

The diaphragm in mammals is the main inspiratory muscle. Studies in hamsters show that there are decreases in the rate of both contraction and relaxation of the diaphragm with age. Tensions per cross-sectional area of the diaphragm are reduced, and the velocity of its shortening is slowed. These functional changes may reflect less activated actinomycin cross-links in older animals, decreases in rates of cross-bridge cycling, and reduced actinomycin ATPase activity.

Effects of Aging on the Regulation of Respiration

Ventilation is controlled reflexly through the mediation of chemo- and mechanoreceptors but can also be controlled deliberately and can be modified via the action of suprapontine brain centers, which can alter breathing as emotional conditions and states of alertness change. In the awake state, the behavioral and reflex controls interact to shape ventilation patterns and allow impediments to breathing to be detected. During sleep, breathing is mostly controlled reflexly, but sleep is interrupted by an arousal mechanism when breathing difficulties occur.

Chemoreceptors in the carotid and aortic bodies are responsible for the changes in ventilation that accompany alterations in the partial pressure of oxygen in the arterial blood. Central chemoreceptors located at multiple sites in the medulla primarily mediate the ventilatory responses that occur with changes in pCO_2. These chemoreceptors are critical for the maintenance of normal body oxygenation and acid–base balance. The sensitivity of the chemoreceptors is assessed from measurements of the ratio of changes in ventilation to changes in blood gas when breathing or rebreathing various gas mixtures containing oxygen and carbon dioxide. The effects of age on respiratory chemoresponses remain uncertain. Several published reports describe age-related decreases in respiratory responses to chemical stimuli. Other studies, however, have failed to note any significant differences in the responses of young and elderly people. On average, the ventilatory responses to hypercapnia are usually lower in older subjects as compared to young subjects. However, the interindividual variability in

responses is so great that group differences are usually not statistically significant.

Similarly, the results of studies of the effects of aging on hypoxic ventilatory responses vary. Some studies have reported attenuated ventilatory responses to hypoxia in elderly adults. A decrease in type I cells, the O_2-sensitive cells in the carotid body, has been reported in the elderly. In contrast, other investigations indicate that hypoxic ventilatory responses, particularly when measured at normal resting pCO_2 levels, are actually higher in the elderly as compared to young people.

There is an important synergistic interaction between the responses to hypercapnia and hypoxia, and the strength of the interaction may vary with age. Whereas in the young there is a multiplicative interaction between hypoxia and hypercapnia (i.e., hypercapnic ventilatory response slopes are steeper during hypoxia than during hyperoxia), in the elderly hypoxia has only an additive effect on hypercapnic responses, with no change in CO_2 response slopes.

This alteration in respiratory regulation in the elderly is probably due to age-related changes in central respiratory neuronal activity. Changes in ventilatory system mechanical properties and respiratory muscle strength found in the elderly are not sufficiently severe to account for changes in ventilatory chemoresponses.

In addition to chemoreceptors, there are other systems that provide information to the central respiratory controller about the state of the lungs and the respiratory muscles. Vagal receptors, including stretch receptors, irritant receptors, and J-receptors, report volume, flow, and pressures within and around the airways and lungs. Respiratory muscle receptors, including muscle spindles, and tendon organs monitor muscle length and tension. Reflexes involving these mechanoreceptor inputs help control the pattern of breathing and mediate adjustments in breathing when the mechanical properties of the lung are rendered abnormal by disease. For example, some diseases may increase the fibrous tissue in the lung (e.g., many occupational lung diseases), making the lungs stiffer. Other diseases (e.g., asthma) narrow the airways and increase the resistance to airflow. In both instances, greater muscular force is required for ventilation, and the activity of respiratory muscle receptors may be altered.

Emotions such as anxiety tend to accelerate breathing rates, lowering expiratory time. In addition, a wakefulness drive prevents the lowering of CO_2 partial pressures (hypocapnia) from producing apnea. A period of voluntary hyperventilation in awake individuals is rarely followed by a period of apnea, but apnea does occur in persons who have cerebrovascular disease, indicating an abnormality in wakefulness drives. The effect of voluntary hyperventilation in the elderly has not been studied.

Changes in the elastic and resistive properties of the lung can be perceived consciously and can be simulated with externally applied devices. Respiratory mechanoreceptor afferents transmitted to higher brain centers may subserve some of the sensations associated with the act of breathing. Psychophysical studies of respiratory sensations have shown that the perceived magnitude of externally applied elastic and resistive ventilatory loads is reduced in the elderly. This impairment of ventilatory load sensation is consistent with other age-related changes in perceptual sensitivity. Advancing age is associated with a reduced ability to detect changes in joint motion, vibration, and heaviness of lifted weights. This suggests that blunted respiratory sensation in the elderly is due to a generalized loss of kinesthetic sensibility.

Breathing During Sleep in the Elderly

Breathing during sleep becomes more variable with aging. Sometimes breathing during sleep ceases momentarily but repeatedly during the night. These episodes of sleep apnea occur more frequently in older than in younger individuals. Apneas are of two types: central, in which respiratory effort stops, and obstructive, in which respiratory efforts continue but no air enters the lungs because of blockage in the upper airway. Both types of apnea occur more often in the elderly. Periodic breathing, a waxing and waning of respiration during sleep, is also more common in the elderly and contributes to the occurrence of both central and obstructive apneas.

Why sleep apneas occur more often in the elderly is still uncertain. A number of different mechanisms may be involved, including the sensitivity of the chest wall and upper airway muscles to chemical and mechanical stimulation and the strength of wakefulness drives.

Sleep consists of two distinct stages: rapid eye movement (REM) sleep, which is generally associated with dreaming and rapid movements of the eyes, and non-REM sleep (NREM). Responses to hypoxia and hypercapnia diminish during NREM sleep and diminish even more so during REM sleep. A study in animals demonstrated no changes in the ventilation response to CO_2 during sleep with age, but the response to hypoxia was not studied. Responses to mechanical stimulation of the upper airways are generally diminished during sleep, but the effect of aging on these responses is not known.

The patency of the upper airway during sleep depends on the activity of the upper airway muscles. Many of the laryngeal and pharyngeal muscles, in addition to their protective function, display a respiratory rhythm that during inspiration serves to stiffen and dilate the airways. With inspiration the pressure in the airways becomes subatmospheric. The upper airways tend to collapse with the negative pressure produced in the pharynx and larynx during inspiration if these muscles are not appropriately activated. Like the diaphragm and the intercostal muscles that move the ribs, the activity of the upper airway muscles increases with hypoxia and hypercapnia. The tongue muscles, which widen the pharynx, and the laryngeal abductor muscles, which widen the laryngeal aperture, contract more forcefully when CO_2 is raised or when O_2 levels are decreased. Sleep has a much greater depressant effect on the activity of these upper airway muscles than on the thoracic muscles. Thus, airway obstruction is more likely to occur during sleep than it is during wakefulness. Snoring is a result of partial obstruction of the upper airways.

Cyclic changes in the activity of upper airway muscles and the diaphragm have been observed during periodic breathing. Poor coordination of the activities of the upper airway muscles and the inspiratory chest wall muscles such as the diaphragm, particularly during periodic breathing, may be an important cause of both central and obstructive apneas in the elderly.

Although there have been very few studies of the upper airways in the elderly, in younger individuals differences in the ability of the upper airway muscles to respond to chemical or reflex stimulation have not yet been found. No anatomical differences in upper airway diameters between young and old were found in one study in humans that used computerized axial tomography (CAT) scanning to assess upper airway cross-section. However, in edentulous individuals the upper airway is narrowed and obstructive sleep apneas are more common.

The intermittent hypoxia that occurs with sleep apnea and the surges in sympathetic activity that accompany arousals from apnea have adverse health effects that predispose the individual to pulmonary and systemic hypertension and that have been implicated in epidemiological studies in causing diabetes, strokes, and heart attacks.

The Effect of Aging on the Defenses of the Lungs

Table 2 lists the mechanisms that protect the lungs. Aging affects both the innate and adaptive arms of the immune system. The elderly are at greater risk for viral and bacterial infections of the lung, conditions that suggest deficiencies in immune response.

Table 2 Respiratory defense mechanisms

Reflex
Gag reflex
Cough reflex
Sneezing
Multicellular
Mucociliary ladder
Cellular
Polymorpholeukocytes
T and B lymphocytes
Natural killer cells
Systemic and alveolar macrophages
Dendritic cells
Extracellular
Antibodies
Complement
Cytokines
Chemokines
Antiproteases
Anti-oxidants
Multisystem warning signals
Fever
Dyspnea
Leukocytosis

The gag reflex is diminished in the elderly so that aspiration of material from the pharynx into the lungs is more likely, as are pneumonias. The airways of the elderly respond normally to challenges by bronchoconstrictors such as methacholine. The lower airways also contain receptors that allow them to constrict or dilate when stimulated via the autonomic nervous system. Generally, the response to such stimulation is smaller in the elderly, which may help limit particle access to the alveoli.

The clearance of particles in the airways of the lung occurs by movement of cilia in the airway that are embedded in a lining layer of mucus. This mucociliary clearance is diminished with aging. Ultrastructural changes have been observed in the tracheal glands, and the composition of the mucous blanket is changed so that its viscosity is increased with age.

Inflammation in the lungs caused by inhaled injurious elements leads to the release of enzymes that cause tissue breakdown. Destruction of the extracellular matrix of the lung, a complex structure composed of long-chain proteins such as collagen, elastin, laminin, and gelatin, is central in the pathogenesis of emphysema. Proteolytic enzymes found in the lungs are of three types, serine proteases, cysteine proteases, and matrix metalloproteinases. They are produced in the respiratory tract by macrophages and bronchial epithelial cells but mainly by the influx of neutrophils that occurs during inflammation. Neutrophil elastase, an important serine protease, is inactivated by antiproteases such as α1-antitrypsin.

Oxygen radicals released during inflammation also promote lung injury. Extracellular oxidants such as glutathione peroxidase are upregulated in conditions of oxidative stress, such as during cigarette smoking.

A number of growth factors are involved in repair processes following tissue damage. One important factor in the lung is TGF-β, which is formed by many different cells in the lung, including epithelial cells and macrophages, and is induced by tissue injury. TGF-β plays a central role in limiting inflammation and in tissue remodeling and repair. However, overexpression of TGF-β and its receptors leads to pulmonary fibrosis.

Neutrophil function is reduced by aging and leads to decreased ability to phagocytize and to release superoxides and proteases. There is some decrease in chemotactic ability in those over 80.

Alveolar macrophages are of major importance in lung defenses. Alveolar macrophages are a unique type of cell that differs from other macrophages in types of receptors, antigen presenting capacity, and eicosanoid production. They are involved in the clearance of foreign proteins and inflammatory cells. Alveolar macrophages also have a regulatory function and initiate signaling cascades during inflammation and in repair processes. They secrete diverse substances, such as leukotrienes, cytokines, proteases, and antiproteases. Macrophages may help modify lung fibrosis. Macrophage function does not seem to change appreciably with age.

However, there are substantial deficiencies in the activity of T and B lymphocytes with age. B lymphocytes are able to produce less immunoglobulin, but the ability to produce autoantibodies has been reported to be greater. This may lead to poorer immune regulation by suppression in the elderly. T cells show less proliferative response to antigens or to mitogens such as plant lectins. The production of cytokines (chemicals important in the immune response) by T lymphocytes is also lower, with decreases in both interleukin-1 and -2 formation. Tumor cell lysis is less, as is natural killer cell activity.

There is an age-related expansion of undifferentiated lymphocytes. These T cell changes appear to be related to reduced secretions of thymic hormones.

Other changes in immune function occur with the aging process. Responses to skin antigens are decreased in the elderly, but reactivity to most antigens in the inspired air is not. Immune responses to tuberculosis as measured by tuberculin test responsivity are reduced.

Decreases in lung defenses probably contribute to bronchitis, pneumonia, and chronic obstructive lung disease, which are common illnesses in the elderly. But an additional problem is the absence of the usual systemic signs and symptoms of lung infection. The elderly frequently fail to become febrile with an acute infection or to mount an appreciable increase in white cell count. Many times confusion is the main symptom of a serious infection. In addition, sensations of breathless are sometimes blunted in the elderly. This increases the difficulty of diagnosing community-acquired pneumonia and pulmonary emboli, which are frequent life-ending events, and may delay appropriate treatment. While some elderly develop significant impairment of respiratory function, others, perhaps by adopting appropriate lifestyles, are able to maintain nearly normal respiratory capacity.

See also: Brain and Central Nervous System; Cardiovascular System; Immune System; Sleep.

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Retirement

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Glossary

Retired Person – Someone with a lengthy work history who has experienced a substantial reduction in employment, accompanied by retirement pension income.

Retirement – (1) The institutional arrangements that provide retirement pensions and rules of eligibility for retirement. (2) The transition between a lifestyle that includes a substantial amount of employment and a lifestyle focused mainly on retirement. (3) The life stage following retirement from the labor force.

Retirement Pension – A periodic payment, usually linked to past earnings and years of service, provided to those who meet retirement eligibility rules, usually age and/or years of service.

Introduction

To society, retirement is a social institution consisting of rules of permissible and required exit from the labor force based on age or length of service and the financial arrangements for creating and delivering retirement pensions. To individual workers, retirement is the transition to a life stage that does not require employment. As an individual attribute, retirement is characterized by withdrawal from the labor force and support from one or more retirement pensions.

The Importance of Retirement to Society

Industrial societies today have well-developed financial and social arrangements for the orderly withdrawal of aging and older people from the labor force. Although the specifics of retirement policies and financing differ considerably across countries, more than 90% of the population age 65 or older is retired in a large majority of industrial nations. In addition, non-industrial nations have adopted features of the retirement institution in selected areas of their economies, especially in civil service and in the military.

Although retirement is quite similar from one industrial society to another in terms of the proportion of elders who are retired, eligibility rules and financing mechanisms vary considerably, and forces influencing retirement policies are often culture specific. Exploring international variations in retirement is beyond the scope of this discussion. Instead, the development of retirement in the United States is used as a case study to illustrate various concepts and theories concerning retirement's origins, functions, and development.

As a social institution, retirement revolves around two important sets of social policies: (1) rules establishing eligibility for retirement pensions, and (2) policies that gather the financial resources to pay retirement pensions. As a result of the develop ment of retirement, industrial societies allocate about 10% of gross domestic product to public Social Security-type retirement pensions alone. In addition, 20–30% of all stocks, bonds, and government securities in the United States are held by employee pension programs.

Individuals usually see retirement as an emancipatory life stage, one in which the individual is free

to decide for him- or herself what goals to pursue. At retirement, individuals see themselves as shifting from working for someone else to working for themselves. Employers see retirement as an effective labor management device that allows them to reduce their labor force or replace less desirable (older) workers with more desirable (younger) workers. Legislators and administration policy makers, however, tend to be ambivalent about retirement. On the one hand, they see it as an appropriate individual reward for lengthy employment service and as a significant social achievement. On the other hand, they view retirement as a social problem that 'wastes' potentially productive human resources and places an economic 'burden' on society.

Few in this cast of characters understand a basic underlying function of retirement: controlling unemployment in high-energy industrial societies. In industrial and postindustrial societies, most physical work is done by machines, which continue to displace people in the economy at a breathtaking pace, especially in the production sectors of the economy. For example, in the United States in 1930, electric power delivered to commerce and industry provided energy equivalent to the effort of 365 million people. By 1980, the use of electric power by industry was equivalent to the work of 6.9 billion human beings. Today, computerized 'expert systems' displace professional and technical employees as well as clerical workers and industrial wage laborers.

High unemployment has historically been a major source of political instability in industrial democracies, and various social policies evolved that on the surface addressed the public welfare but also had the important function of reducing the size of the labor pool competing for available jobs. Child labor and compulsory education laws removed children from labor competition, and retirement removed older people. Enormous public expenditures go to provide the educational institutions that keep young people occupied. Likewise, public revenues are usually a major source of retirement income in all industrial democracies. Industrial societies need well-educated workers, and elders certainly benefit from having a period of retirement following a lengthy employment history, but the important relation between retirement and the need to control unemployment is a mostly invisible engine that drives the need for retirement. Accordingly, retirement policies have become more liberal in times of high unemployment and more stringent in times of labor shortage. For example, the minimum retirement age tends to drop in response to high unemployment, whereas retirement incentive plans tend to disappear during labor shortages. The benefits of industrial production are many, but there are also costs, and retirement is an important and usual cost of living in industrial societies (*see* Work and Employment: Individual; Work and Employment: Society).

Concepts

Retirement pensions provide the means for carrying out retirement. Without pensions, retirement is possible only for the economic elite. Pensions come in many varieties: public social insurance retirement pensions such as Social Security; employer pensions that provide a defined benefit amount per month, usually based on a formula tied to years of service and earnings; employee pensions based on defined contributions by the employer, the employee, or both, which can often be taken as a lump sum or as a monthly annuity; and self-initiated retirement annuities, many of which are encouraged by tax shelters.

In essence, 'retired person' is an individual status earned by many years of service in the workforce. It is morally approved and economically supported as a legitimate earned right. At the same time, the status of the retired person is presumed to be voluntary. Operationally, a retired person can be defined as someone with a lengthy work history who has experienced at least partial withdrawal from the labor force, accompanied by retirement income earned through prior employment. Retired person can also be a subjectively assigned personal attribute, and in addition is sometimes used as a euphemism for an older person. However, as a legitimate status attribute, retired person is an achieved status, not an ascribed status based solely on age.

Determining retirement status is relatively easy for people who work continuously for 40 years or more and then retire completely, but other categories are more ambiguous. For example, people who 'retire' from one job only to take another full-time job may consider themselves retired and may receive a retirement pension, but are they really retired? What about people who worked only sporadically and thus do not qualify for a retirement pension but who see their means-tested welfare benefit as a retirement pension and label themselves as retired? As the idealized pattern of a long work career followed by abrupt and complete retirement becomes less and less common, defining who is retired becomes more complex and more difficult.

Retirement is also a life transition during which a person moves from full-time employment to no employment. Retirement pensions usually begin when employment is substantially reduced. For some, this transition is abrupt, but an increasing

number of people experience 'bridge' employment, which often involves fewer hours or weeks of employment, sometimes at reduced pay or occupational status, for some period of time before they withdraw completely from the labor force. A broader definition of the retirement transition includes a period of preparation for retirement and a period of adjustment to retirement. By either definition, retirement transitions vary greatly in length and may span a considerable period of time. However, by age 75 all but a very small proportion of adults in industrial societies have withdrawn completely from the labor force.

Retirement is also a life stage that follows a lengthy period of reasonably continuous employment during adulthood. It emphasizes a lifestyle that includes an array of social roles appropriate to a person who is no longer required to be part of the labor force. Retirement is literally a 'do-it-yourself' life stage in that the only cultural expectation of retired people is that they avoid competing for full-time jobs, and even this norm is only half-heartedly applied. Retirement lifestyles can be built around a wide variety of activities such as sports, travel, community service, religious activities, maintaining a home, landscape or vegetable gardening, spiritual contemplation, or taking care of grandchildren. However, the 'busy ethic' requires that retired people remain productively engaged in some way (*see* Leisure).

Retirement is also a social institution made up of a cultural rationale for retirement and a complex array of social policies that establish rules under which people are allowed or encouraged to retire and that provide mechanisms for financing retirement. Ageism – prejudice against aging or older people – is at the heart of the cultural rationale for retirement as a social institution. All industrial societies espouse a widespread cultural belief that aging has profound cognitive and physical effects that interfere with an aging person's capability to engage in productive employment. This often erroneous belief legitimates employment policies that discriminate against middle-aged and older people seeking jobs and that encourage retirement long before the onset of old age, if old age is defined symptomatically as significant physical or mental incapacity.

However, industrial cultures also contain a long-standing norm of caring for elders, which means that simply discharging middle-aged and older workers is not a morally acceptable option. In order to discriminate against older workers and at the same time preserve the illusion that no harm comes to them from this practice, retirement pensions were developed to prevent elders who were displaced from employment from becoming destitute. The extent to which pension systems are designed to provide pensions that will support preretirement lifestyles depends in large measure on the robustness of the economy, the proportion of elders in the population, and organized political advocacy on behalf of, or in opposition to, retirement pensions.

The underlying rationale for retirement may be cultural, but specific retirement policies are managerial and political. In most cases, employer policies are designed to move workers into retirement at the earliest age possible given the level of funding of the employer pension program. By not allowing pensions to increase with years of service beyond the minimum retirement age and/or years of service requirements, employer pensions often contain strong economic incentives to retire. Employers use pensions as bargaining tools in negotiations with employees, even in the absence of unions, particularly as a way of deferring wages into the future.

Public retirement programs are governed by policies developed through a political process. Elements of public retirement policies include the proportion of the population covered, funding mechanisms, minimum retirement age, length of service requirements, relation of eligibility and/or benefit amounts to age, retirement tests, links between benefit amounts and career earnings, special provisions for unhealthy occupations, pension supplements for dependents or retirees, indexing of benefits to offset inflation, and the extent to which benefits are expected to replace preretirement earnings from employment. This large complex of interrelated policies is manipulated legislatively to maintain the functioning of the retirement institution within an area bounded by unemployment rates, levels of poverty in old age, adequate pension replacement rates, and public willingness to finance retirement (*see* Economics: Society).

Each of these elements is in turn influenced by a wide array of factors, chiefly, the robustness of the economy, the proportion of elders in the population, and the extent to which the political process is open to influence by class and/or interest group organizations. The goals of public retirement policies are (1) to keep unemployment down by manipulating retirement levels, (2) to minimize the proportion of older people in poverty, (3) to replace at least 60% of preretirement earnings, particularly for low-income workers, in order to minimize the individual financial hardship connected with retirement, and (4) not to exceed the public's willingness to pay. These goals rise and fall in national value systems in parallel with changes in overall political philosophies. In times of concern for societal safety nets, retirement rises on the public priority list. In

times of concern for individual or family wealth accumulation or minimizing government, retirement assumes less importance. To balance constantly changing factors, most retirement systems are continually under adjustment in response to feedback, especially from business cycles. When the complex of factors that influence employer and self-initiated retirement income programs are included alongside issues shaping Social Security-type public retirement systems, retirement can be a very complex social institution indeed.

History of Retirement

Retirement is a creature of modernization, the sociocultural shift that began in the late 1700s and brought new ways of thinking about how to pursue material progress, particularly in the form of more and better goods and a higher general level of living. Key aspects of modernization included the rise of science as a way of knowing, technology as a means of production, hierarchical bureaucracy as a form of organization, universalistic law as a means of social control, individualism as a moral philosophy, communication as a means of generating agreement, and geographic and social mobility as means of matching people with jobs in an increasingly complex division of labor. As an ideal, a modern society is typified by techno-scientific rationality, universal education, mass organization and communications, cosmopolitan urban populations, and political democracy.

But what is it about modernization that caused older people to be singled out for exclusion from the labor force through the development of retirement? The rise of science as a way of knowing, technology as a way of production, and impersonal bureaucratic rule as a way of deciding are all aspects of modernization that played key roles in excluding elders from the pool of workers defined as desirable and in the development of retirement as a method of ensuring society against widespread personal hardship and political instability that could be expected to accompany the wholesale exclusion of elders from the workforce in the absence of retirement pensions (*see* Modernization and Aging).

Early science was crude in both measurement and research design. The first studies of physical and mental aging focused on mean age differences and paid almost no attention to dispersion around the mean. Thus, early medical texts stressed the sharp declines observed in mean level of functioning for various bodily organs and systems. Early psychology texts stressed mean age differences in cognitive functioning. Little or no attention was paid to the enormous variation in functional capacity within age groups, and no studies were based on longitudinal research designs that looked at actual changes over time. In addition, differences in functioning were compared only across age categories, not against a benchmark level of functioning necessary to sustain a normal level of adult activity. As a result, outrageous generalizations were made and believed about the scientific 'evidence' concerning the negative effects of aging. For example, William Osler, physician-in-chief of Johns Hopkins University Hospital, gave a widely reported address in 1905 in which he contended that aging had such profound effects on human creativity and productivity that men older than 40 could be considered benign but relatively useless workers, and men around age 60 were so useless that they represented a drain on an organization and absolutely had to be retired. Although Osler's view was extreme, it was endorsed in milder forms by influential industrial leaders. This erroneous belief in the relative worthlessness of older people as workers remains strong today, and it forms an important part of the belief system that sustains retirement.

Technology increased productivity enormously, but at a tremendous cost in terms of a net loss of jobs. For example, mechanization of agriculture began to displace farmers and farm workers from the land in large numbers after the American Civil War in the late 1860s. Rapid cycles of technological change led to wide short-term fluctuations in urban industrial employment. Unrest and mob violence associated with cycles of very high unemployment led employers, labor leaders, and politicians to search for ways to moderate the unemployment effects of business cycles.

Retirement was a potential solution to the problems of excess workers, but as long as work organizations were small and proprietary and the relatively few older workers who had to be assigned to lighter work could be paid lower wages, personal relationships insulated older workers from ageism to a great extent. Older workers tended to be dealt with as individuals rather than as members of an age category. However, with the growth of corporate management forms and impersonal, bureaucratic organizational policies, it became possible to justify and implement universalistic policies based on assumed characteristics of age categories. Individual characteristics no longer mattered, nor did variations within age categories.

But as long as retirement was not accompanied by pensions, employers were reluctant to simply throw out older workers. In the United States, the spread of employer pensions in the 1920s and passage of

Social Security legislation in 1935 provided basic models for retirement financing. In the 1950s, changes in labor and tax laws allowed collective bargaining to rapidly expand employer pension coverage. These changes combined to provide a financial foundation for the adoption of retirement as a universal social expectation. Similar systems developed throughout the industrial nations.

In summary, ageism in science, displacement of older workers by technology, and bureaucratic impersonality all combined to devalue older workers and to justify their exclusion from the labor force. The development of public and employer pensions provided the stimulus that attracted workers to retirement.

Current Retirement Trends

In society, levels of retirement gradually increase in response to maturing retirement pension systems. In the United States, the average age of first retirement began to decline in the 1950s. The decline accelerated in the 1970s, leveled off in the 1980s, and then began to increased in the mid-1990s. In 1950, most American workers felt that retirement was justified only if the individual was physically unable to continue working, but by 1960 most said that retirement was legitimate if the individual wanted to retire and had a pension to support it. By 1975, a large majority of American workers had very positive attitudes toward their own retirement. By 2000, a large majority still had a favorable attitude toward retirement, but had much less faith in the capacity of pensions and Social Security to provide the promised retirement income.

Retirement decisions are sensitive to both the lure of pension generosity and the opportunity for continued employment. After 2000, the uncertainty of pensions and retiree health benefits caused more prospective retirees to have second thoughts. This factor is related to fluctuating faith in the governmental systems that ensure pension systems and health-care benefits for retirees. In recent years, both have become more problematic throughout the industrial world. Public discussions of these trends often invoke a demographic argument that retirement is not sustainable in an aging society, but close examination reveals that the most important factor is political willingness to use economic resources to support retirement. In the United States, polls continually show very high public support for programs that ensure adequate pensions and health care for retirees, but political policy makers seem more responsive to voices coming from leaders of commerce and industry, who want to minimize their labor costs.

Early first retirements are not necessarily complete retirements. In the 1980s, labor force data in the United States began to reveal a pattern of 'bridge employment,' a period of continued employment, often full-time, that bridged the point at which the individual began to draw a private pension and the point at which the person could receive Social Security benefits. By 1990, more than half of men who retired completely were retiring from bridge jobs.

Retirement is becoming an increasingly diverse set of patterns: (1) continuation into retirement of occupational inequalities in income and health-care insurance, (2) different age patterns of retirement, and (3) divergent meanings of retirement. Although public Social Security-type pensions provide nearly universal access to retirement in all industrial societies, various rules concerning years of service and benefit computation formulas tend to be a disadvantage for those who have spent significant amounts of time as adults outside the labor force. Sporadic work histories are most common among women, particularly those who drop out of the labor force for childrearing or other types of caregiving.

Industrial societies all have social class and minority group inequalities in opportunities to generate adequate retirement income, but these inequalities range from substantial to trivial. Nations with strong welfare states tend to have strong safety nets and small inequalities in access to retirement income and health care, whereas nations with relatively weak welfare states tend to have much greater inequalities in access to retirement income and health care. But most retirement institutions recapitulate the wage inequalities of the occupational system. Nevertheless, in the latter half of the twentieth century, the maturation of retirement in industrial societies was a major factor in the reduction of poverty associated with old age.

Retirement lifestyles have become increasingly diverse. For some, retirement means a life of leisure, which can take many forms. For others, retirement is an opportunity to become self-employed. Others retire to a life of community service. An increasing number retire into the family by taking on responsibility for caregiving of grandchildren or providing long-term care to older family members. Many retire to a life of couplehood. As people live out retirement as a life stage, they may experience several of these different lifestyles. Increasingly, retirement is coming to be seen as an active life stage that occurs between the cessation of employment and the onset of the frailties that can come with old age. When frailty becomes the organizing principle of one's lifestyle,

the idea of a retirement lifestyle diminishes in importance, even though the person is still retired and receiving a pension.

Effects of Retirement on Individuals and Households

Early gerontologists thought that retirement had a great number of negative effects. In addition to financial difficulties, retirement was said to cause demoralization and a loss of self-esteem, reduced activity levels, increased isolation and loneliness, increased feelings of uselessness, and declining physical and mental health. Many gerontologists thought that the root of these negative outcomes was psychic damage caused by the loss of an occupational identity. It is true that demoralization, low activity levels, and so on could be found among retired people, but most of these unfortunate outcomes were caused by the extremely low retirement incomes of the 1950s. By 1975, cross-national studies that followed people through the retirement transition were finding that retirement had little or no effect on physical or mental health, overall activity levels, social participation, or life satisfaction. It became increasingly clear that depression attributable to retirement was a rare outcome. Given adequate retirement income, most adults were found to adjust very well to the life changes associated with retirement.

Likewise, early literature on retirement assumed that retirement represented a major upheaval for most married couple households, particularly due to the invasion of a traditional 'wife's domain' by newly retired husbands. Again, research showed a different picture. Although there are certainly adjustments that must be made when a working household becomes a retired household, most couples adapt to many significant changes in the course of their marriage, and retirement is well within their coping capacity as a couple. Those couples who have a troublesome relationship in retirement tend to have had troublesome relationships in earlier life stages as well.

Why is retirement such an easy adjustment for most people? First, given adequate retirement income, people can relax about the adjustment process because they do not have to worry about securing the next month's income. Second, most people anticipate retirement and have watched others retire before them. As a result, they do not feel that they are stepping into unmapped territory. There are many clearly marked paths and effective role models. Third, retirement is a morally sanctioned life change. The cultural life course concept in industrial societies defines retirement as an earned reward financed from the productivity of an economic system that individual workers helped to create through their lengthy employment, a reward that individuals ought to and do feel good about accepting. Fourth, as a cultural life stage, retirement still requires individuals to have goals and to engage in productive work, even though it may not be for pay. This expectation of continued productive activity maintains the sense of self as competent and worthy.

Although a large majority of people who willingly retire accomplish the transition with minimal stress and find a satisfying retirement lifestyle within a relatively short time, the small proportion who are coerced into retirement are more likely to experience difficulty. For example, although the practice is often illegal, some workers are given two unattractive choices: retire before they are ready or see their jobs be terminated. Most choose retirement over unemployment, but some cannot be happy about the circumstances under which they retired. They may still have unfinished occupational goals, retirement earlier than expected may result in retirement income lower than they see as adequate, and they may not be ready to relinquish the position of worker. Nevertheless, within a year or two, most reluctant retirees have either found another full-time job or have adjusted well to life in retirement.

Another category of unhappy retirees consists of those who retired for health reasons. If health deteriorates to the point of being so disabling that it forces an individual to retire, no one should be surprised that disability and the constraints on activity that come with it continue into retirement. In these cases, disability, not retirement, is the cause of constricted life space and any attendant psychological distress. Fortunately, the proportion of people retiring for health reasons has dropped dramatically since the 1960s.

Explanations of Retirement

Why does retirement exist? What factors have been responsible for the rapid evolution of retirement and the directions this evolution has taken? What accounts for the rapid public acceptance of retirement, especially in work-oriented societies? Why has retirement been called into question by the very economic, governmental, and political interests that gave rise to it in the first place? These central questions have stimulated social gerontologists to develop a number of explanations.

Why does retirement exist? The idea of retirement from the pressures of economic and social life in one's 60s to lead a life of contemplation and spiritual

growth can be traced back more than 4000 years to the Hindu Vedas. A few medieval farmers deeded their land to their sons or to the church in exchange for a guarantee of food, shelter, and care in retirement. Wealthy merchants could retire and live on the proceeds of their wealth. But retirement has been an economic possibility for most workers only since the advent of modern industrial societies. Why did we create such ambitious and effective systems of financing to provide retirement for the masses? Explanations center around functionalist and exchange theories. Functional theory presumes that retirement is caused by functional needs, particularly the need to control unemployment. As mentioned previously, industrial societies have historically had difficulty providing full employment, and retirement serves an important unemployment control function by systematically removing a sizable segment of the adult population from labor market competition. However, in democratic societies, retirement must primarily be implemented by persuasion and incentive rather than by coercion. Thus, government pensions systems must provide pensions generous enough to attract large numbers of older workers into retirement.

Exchange theory argues that retirement is a result of age discrimination. According to this theory, employers want to hire workers who will give the greatest value in exchange for wages. People in the labor market are not viewed as individuals with unique talents and skills; instead, employers sort potential employees into categories and arrange these categories into a hierarchy of relative desirability in terms of the resources people in the category are assumed to bring to the exchange. In this context, the category of 'older worker' begins at about age 50. Older workers are widely believed to bring fewer resources to the employment transaction in comparison with other categories of adults. Older workers are assumed to have less stamina, less up-to-date education, less ambition, and less creativity. They are assumed to cost more, bring a lower return on training, derive less benefit from training, and resist new technologies. Research evidence indicates that these beliefs are inaccurate, but what matters in the exchange is that managers and policy makers act on these beliefs as if they were true and do not want or need proof in order to act.

Thus, organizations are motivated to create ways of keeping to a minimum the number of employees in the older worker category. They do not hire older workers if they have other alternatives, and they seek ways of moving older workers out of the organization as soon as possible once they enter the older category. To many managers, the only good older worker is a retired older worker. Retirement was developed to provide a means of humanely disposing of workers presumed to be less effective. Again, in industrial democracies, incentives are preferred over coercive policies.

Functional and exchange theories of retirement complement one another. Both accept the notion that older workers are a category that can be legitimately excluded from the labor force. Functional theory focuses on effects of this exclusion on unemployment in the economy as a whole, whereas exchange theory focuses on the presumed benefits of this exclusion for employer organizations. The widespread acceptance of cultural myths about negative effects of aging on employability is foundational for both theories. These theories also help to explain why retirement is encouraged at an age long before the frailties of old age become prevalent in a population cohort.

Some functionalists argue that retirement serves the function of humanely removing people disabled by aging from the labor force. But as a social institution, retirement is not primarily concerned with disabled elders. Indeed, in most societies, disability retirement is handled by a completely different system than service retirement. Retirement policies are designed to encourage older workers, who are assumed to be less effective but who are not usually disabled, to withdraw from employment. Elders who are physically or mentally unable to work can be dealt with through disability pensions, so retirement pensions are not needed for this function.

Other functionalists argue that retirement arose to meet workers' desires for leisure. But this argument has a substantial causal order problem, because retirement pension systems were developed long before a majority of industrial workers began to see retirement as a legitimate individual goal.

But if retirement's major function is simply to remove workers from the labor force, how do we explain the fact that retirement institutions in most societies deliver pensions more generous than would be needed simply to allow people to survive outside the labor force? Pension benefits are usually much more generous than means-tested welfare benefits. Evidence indicates that a large number of workers can be attracted from the labor force with pensions amounting to only 40% of preretirement earnings, but many public retirement systems in the industrial world provide 60% or more earnings replacement. The theoretical answers to this question come from political economy theory, moral economy theory, and social justice theory.

The political economy theory of the dynamics of retirement as an institution starts from several basic

assumptions: most industrial societies are capitalist, capitalist economies exploit workers unless confronted by organized opposition from labor, most industrial societies are democracies, and democratic politics provides a vehicle through which labor, organized or not, can achieve just treatment in the form of adequate retirement benefits. In this frame of reference, the adequacy of retirement benefits is a function of the political power of wage and salary workers. This power can be exercised in one of two ways: through direct negotiations between organized labor and management or through the capacity of advocates for the interests of workers to influence the legislative processes through which public pension formulas are set and rules governing employer pensions are made.

Moral economy theory assumes that raw economic power or political power is not enough to explain the generosity of retirement pensions. Moral economy theory holds that the economy is not just a matter of financial obligations and that for a highly interdependent industrial economy to function, there must also be moral commitments that go beyond simple payment of wages or salaries. These extended commitments provide a sense of security needed for workers to be able to concentrate on doing their jobs productively. Thus, moral economy theory assumes that current wages and other benefits do not fully compensate workers for their labor and that part of their just compensation consists of moral commitments by the society to provide both protection from unemployment and adequate income in retirement. Retirement income is not the only benefit that comes under the moral economy. In the United States, retirees and their dependants are the only major social category covered by national health insurance.

Social justice theory is based on the concept of civil rights. It assumes that eligibility for adequate retirement benefits is a right earned by all residents who participate in the workforce throughout a major portion of their adult lives. The rationale is that in affluent industrial societies, there is no justification for retirees to be disadvantaged by being forced by age discrimination to survive on less than adequate retirement benefits. This perspective helped fuel the successful movement for more adequate Social Security pensions, which began in the 1960s when a large proportion of Social Security pensioners had incomes below the poverty line.

Note that the issue is not whether retirement should exist. That tends to be taken as a given by political economy, moral economy, and social justice theories alike. The issue is the adequacy and fairness of the compensation retirees should receive for leaving the workforce. Evidence indicates that each of these perspectives helps explain the development of retirement.

The nature industrial capitalist economies and political democracy may explain why retirement is needed by society and how retirement benefits came to be at least adequate if not generous. But why does such a large majority of individuals go willingly into retirement, especially if retirement is not mandatory? This question is addressed by theories of individualism and human development.

Individualism as a personal philosophy is at the heart of industrial societies. Young people are socialized to pursue their own individual talents and aggressively seek opportunities in the complex division of labor. Individual freedom and self-determination are held up as high rewards. Retirement may have been created initially as a way to institutionalize age discrimination in employment, but so long as the payoff is adequate, many employees are quite willing to take even a sizable pay cut in exchange for the level of freedom and self-determination that retirement offers.

Adult development theory also offers explanations for why individuals might be attracted to retirement. Few career ladders extend indefinitely. In fact, the concept of career probably poorly describes the succession of jobs that many individuals experience. For those stuck in career or job plateaus, switching job fields is constrained by age discrimination in employment. And even if new jobs were available, the person still may feel at the mercy of another boss. Retirement is a growth option because it offers a secure income and a chance to become one's own boss.

Movement away from a focus on material acquisition and social position represents another developmental support for individual acceptance of retirement. Many adults find that the preoccupation with material acquisition and social position that characterized young and middle adulthood becomes less satisfying over time. These people see more meaning in the quality of everyday life, and retirement gives them more control over that quality than they can achieve if they are still integrated into employer organizations, particularly in a time of growing employer pressures for ever-increasing pace and amount of productivity. For example, as leisure time contracts in the face of job demands, many adults experience a degradation in their quality of life, and they see retirement as an attractive way to restore a better balance of both control and life quality. They also have experienced material acquisition and achievement of social position and often find them overrated as sources of ongoing life satisfaction. They increasingly find themselves drawn to

what they see as a more relaxed and humane pace of life, more control over their personal life goals, and more time for personal relationships and satisfying activities. The informal relationship networks of retired people often resemble a congenial extended family, and the lifestyles of most retired people revolve around meaningful and satisfying activities.

The advantages of retirement have become institutionalized through the packaging, marketing, and advertising of retirement as prepaid leisure. Industries that have formed around individual retirement needs include retirement planning, retirement personal finance, and retirement housing. In recent years, a worldwide network of programs has developed to satisfy the needs of retirees for ongoing education. The offerings of this network span an enormous variety of subjects and are offered all over the world.

Thus, adults go willingly into retirement even though it represents a decline in social status and nothing less than institutionalized age discrimination because for them the benefits, in the form of freedom and enhanced quality of life at the personal level, far outweigh the costs in terms of lost abstract social status.

Why has retirement been called into question by both business and government in many industrial societies? In the United States, the institution of retirement has been under a sustained political and managerial attack since the late 1970s. Part of this assault is based on philosophical opposition to government operations in areas in which private enterprise sees potential business opportunities. Thus, Social Security is criticized on the grounds that private retirement programs could bring workers a better 'return on investment.' That Social Security is social insurance and not intended to be an investment is ignored. These critics also usually ignore survivor, disability, and health benefits that are part of Social Security and imply that retirement benefits are the only return workers get for their Social Security taxes. These arguments are put forward by a financial services industry made up of insurance companies, banks, and securities firms who want to 'privatize' all or part of Social Security in order to increase their own business opportunities.

Employers also want to reduce their Social Security tax liabilities. Corporate income taxes have fallen much faster that individual income taxes in the United States since 1970, whereas the employer's share of Social Security payroll taxes increased from 3% of earnings up to $4200 per year in 1960 to 7.65% of earnings up to $60 600 in 2004. Reducing Social Security taxes is a major policy objective of the American business community. Employers want Social Security to continue to draw older workers out of the labor force, but employers do not want to pay their share of the cost of this benefit.

The financial services industry and business advocates joined forces to mount a well-organized campaign to convince the public that Social Security could not be sustained economically. According to their argument, the rapid increase in older population that will come with the entry of the baby boom population into retirement is bound to bankrupt the system; therefore, people who are currently paying Social Security taxes are unlikely to get their full Social Security pensions. This argument flies in the face of many studies showing that under current benefit formulas, providing Social Security pensions for the baby boomers will require only modest changes to the system under any likely economic scenario. Nevertheless, the propaganda campaign has been very successful in that a large proportion of younger workers in the United States thinks that Social Security will not be there when they reach retirement age, even though a very large majority of workers want the program to remain and express willingness to pay higher taxes in order to maintain it. But as more and more younger workers come to believe that the collapse of Social Security is inevitable, resentment of those who currently enjoy Social Security benefits rises and willingness to pay Social Security taxes falls.

Understanding the multidimensional assault on Social Security demands a conflict theory perspective. The history of retirement in the United States illustrates the potential for conflict between opposing philosophies of government. At one extreme are those who feel that the best government is the least government. A procedural state that allows for peaceful resolution of disputes and a common monetary system are about all that is necessary according to this view. A less extreme but still conservative position would add armed forces, police and fire protection, and perhaps education to the list of public institutions. At the other pole are those who wish for a strong national government to protect the public in a number of areas, including pensions, health care, housing, education, science, commerce, banking, environmental protections, public welfare and transportation. The assault on retirement, especially Social Security, can be seen in a context of a general social movement to scale back the resources going into national government. This movement is being partially fueled by pressures on revenues and wages in an increasingly global system of production. This shift is vigorously opposed by those who believe that there are certain functions, such as national retirement pension systems, that only government can perform adequately.

The power of membership organizations or interest groups made up of retired people to assert a voice in favor of retirement protections is unclear. Again, the United States offers a useful example. On the one hand, the media frequently refer to AARP (formerly the American Association of Retired Persons) as 'the most powerful lobby in Washington.' But AARP is a large and diverse organization of 30 million members with all sorts of political orientations. Most AARP members joined to take advantage of AARP's insurance, financial, travel, and pharmacy services, not to be part of a social movement. To protect its non-profit status, AARP cannot give financial support to political candidates. This is in stark contrast to other powerful lobbies such as the National Chamber of Commerce. AARP does not participate in setting political agendas, but instead reacts to political proposals.

In the 1970s, AARP and other organizations advocating for retirees' interests were effective in shaping the national agendas of the congress and various administrations because the climate was sympathetic to government oversight and programming. By 2005, the public remained sympathetic to the need for Social Security and protections for retirees' pension and health-care benefits, but was apathetic or skeptical about the ability of the national government to deliver. The result of this shift has been a steady erosion of government protections and initiatives aimed at adapting the retirement institution to changing circumstances.

The weight of the evidence suggests that regardless of political or economic philosophy, industrial nations generate policies that move a very large proportion of their older populations into retirement. Therefore, political conflict tends to be about the relative generosity of national pensions, not whether or not to have them. There is no reason to expect that the long-standing tension between advocates of strong government and advocates of weak government will abate, and as this ongoing conflict focuses on public pension generosity, Social Security-type retirement systems will change.

The Future of Retirement

The future of retirement is uncertain. It will emerge from the interaction of a number of opposing economic, political, demographic, and social policy concerns. The key question is whether retirement is or even should be sustainable.

At the turn of the twenty-first century, industrial economies of the United States, Europe, and Japan are not the robust forces they were in 1960. Worldwide decentralization of industrial production has destabilized wages and benefits for large segments of the labor forces in industrial nations. Demassification processes have drastically reduced the scale of many types of economic activity, particularly the types of professional, managerial, and technical jobs that formerly carried access to adequate retirement benefits. Retirement institutions are no longer shaped by negotiations among representatives of huge labor unions, large corporations, and national governments. In the United States, as a result of declines in organized labor, reductions in availability of pension coverage, shifting of pensions from defined benefit to defined contribution approaches, shifting of pension plan contributions from being deferred compensation from employers to being an employee responsibility, and rules that allow employees to withdraw their funds from pension programs when they change employers, access to adequate employer pensions among younger workers is becoming increasingly problematic. This increases the pressure for Social Security alone to deliver adequate retirement pensions. Because of the fragmentation of retirement policy, young workers have little faith in retirement as a social institution they can count on.

The longevity revolution is rapidly increasing the proportion of the population surviving beyond age 85. The retired population begins chronologically as early as age 45, but most people retire in their 60s. This means that retirement income programs must be designed to deliver secure retirement income for up to 25 years on average and for up to 50 in many cases. Policy makers have generally advanced two scenarios for responding to the impending masses of retirees: keeping aging people in the workforce longer, and plan to reduce benefits. Institutional supports for adequate retirement benefits are becoming less reliable, particularly for middle- and lower-income workers.

There is no sign that age discrimination in employment will be reversed or that elders will be welcomed to remain employed. Labor shortages resulting from low birth rates among the middle and upper classes are more likely to be offset by increased immigration or by increased use of technology than by creating more job opportunities for older workers. However, if benefits are reduced, many older people, especially those under age 75, may be forced by economic circumstances to stay in the labor force, where for the most part they will compete with immigrants and young people for low-wage jobs in retail and service sectors of the economy. In any case, keeping more elders in the labor force is not likely to be a satisfactory solution should the increased size of the older population outstrip the will of nations to provide retirement income.

The other possibility is to reduce benefits. Currently, those elders in the United States whose

retirement incomes are mainly from Social Security live just above the poverty line. Benefit cuts would make this population eligible for public assistance, which would simply shift the liability for their income from one government program to another. Sharp reduction of Social Security benefits for middle- and upper-income retirees would reduce the revenues needed to sustain Social Security retirement, but middle- and upper-income retirees feel that they have earned their pensions and expect to receive them. They also have the economic resources and educational background to mount effective political action. Across the industrial nations of the world, public support for public retirement pensions is strong, and political opposition to substantial benefit reductions could be expected.

The sheer number of future elders in the baby boom generation scares policy makers, who picture a huge phalanx of older baby boomers taking to the streets to demand adequate retirement benefits. To head off this possibility in the United States, two major actions were taken in 1983: the age for full Social Security benefits was scheduled to increase gradually from 65 to 67, and the scheduled increases in Social Security taxes were advanced in order to build up a sizable surplus in the retirement trust fund that could be used in conjunction with payroll taxes to pay pensions for the baby boomers. But because projections of survival rates among elders have consistently underestimated the number of future older people, the Social Security system has consistently experienced minor shortfalls that have led to calls for revamping the system. Those opposed to public retirement systems claim it is unsustainable, and those favoring the system claim that only minor adjustments would suffice to keep the system solvent. Similar debates are being held in most industrial societies and are difficult to resolve because there is growing disagreement about what constitute the 'facts' and how to interpret them. Relativism and postmodernism undercut the discourse needed to come to societal consensus about most social institutions, including retirement.

The long-term financial viability of public Social Security-type retirement programs depends on the continued voting support of national legislators. For many decades legislative support for Social Security-type public retirement programs has been unwavering in industrial countries, but in recent years economic pressures have caused legislatures to have second thoughts about pension generosity. Questions about the long-term sustainability of these programs in an environment of economic globalization have been a major factor in softening legislative support. As corporations increasingly operate freely across national boundaries, claims on corporate economic surpluses by national governments become more difficult to enforce. If countries push too hard for a share of economic revenue, the fear is that corporations will move operations elsewhere.

At the same time, pubic demand for retirement is showing no signs of diminishing. In the United States, most people retire in their early 60s, before the age of eligibility for full benefits under Social Security. The concept of retirement as an earned right and as prepaid leisure is widespread. People continue to desire the freedom and autonomy of retirement and to feel that they have earned the opportunity. Despite negative images about retirement and aging in the media, most Americans have very positive images of their own lives in retirement. Their major concern is maintaining adequate income and health care in an uncertain economy with high health-care inflation.

In the United States, public and private pension policies are on opposite courses. The political rhetoric advocating changes in Social Security emphasizes keeping people in the labor force longer and reducing retirement benefits. But employer pensions, nearly all of which are subsidized by tax shelters, are geared toward encouraging older workers to exit the labor force at the earliest age possible. These conflicting philosophies reflect a national ambivalence about retirement that is present in most industrial societies. On the one hand, most people who retire could continue to work. On the other hand, there is not likely to be enough work to go around. Long-term unemployment, which was once mainly something that happened to working class people, is beginning to be widespread within the white collar professional and managerial classes as well. The question is whether the political process will adequately compensate elders for leaving the workforce, force them into a lower-income retirement, or require them to stay in the labor force and risk an open struggle with younger people for jobs on the margins of the economy.

What is the alternative to retirement? Legislators and administration policy makers in the developed world cannot expect the public to sit quietly by and watch barely adequate retirement benefits be replaced by predatory employment or poverty. As retirement becomes more problematic, political conflict over retirement will intensify. Nevertheless, if only because of its unemployment control function, retirement will remain an important social institution in postindustrial or high-tech societies.

See also: Economics: Society; Leisure; Modernization and Aging; Work and Employment: Individual; Work and Employment: Society.

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S

Self Esteem

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Glossary

Cohort – Individuals born in the same time period: either the same year or the same decade.

Cohort-Sequential – A design in which individuals from more than one birth cohort are studied at more than one time point. This design allows for a separation of the effects of aging, cohort membership, and social or cultural events.

Cross-Sectional – A design in which a group of individuals is studied at only one time point. Age effects are assumed when age differences are found between individuals in the group. However, age and cohort effects are confounded in this study design.

Longitudinal – A design in which a group of individuals is studied at more than one time point. Age effects are assumed when the same individuals demonstrate change from one time of measurement to another. However, if this study design is used with a single cohort, then age is confounded with time of measurement.

Repeated Cross-Sectional – A design in which different groups of individuals from the same birth cohort are studied at different times. Aging effects are assumed if differences are found between groups at different time points.

Role – Expectations regarding the rights and duties of an individual holding a certain status position in society.

Introduction

The self-concept refers to the totality of one's attitudes toward the self as an object. It is made up of three parts: cognitive, evaluative, and conative components. The cognitive component refers to the way individuals identify themselves in terms of the roles they play or the characteristics they use to describe themselves. The evaluative component represents the extent to which individuals like or dislike their self-defined identity and reflects their self-esteem. The conative component corresponds to individuals' motivations to maintain or change themselves as a result of discrepancies between their real selves and their ideal selves. Because the majority of the empirical work on the self-concept is on self-esteem, it is the focus of this article.

Of concern to gerontologists is the extent to which self-esteem changes or remains stable across the life course. There are reasons to believe that self-esteem may decline in later life because individuals are more likely to encounter ageism, role loss, or health problems. On the other hand, self-esteem may increase in later life as a result of maturational development. Also of concern are the factors that predict self-esteem in older adults. It is important to know the predictors of self-esteem in later adulthood if interventions are to be made. The primary purpose of this article is to examine the theories, methods, and empirical evidence regarding continuity or change in self-esteem over time. A secondary purpose is to describe the predictors of self-esteem among older adults. While the first part of the article largely deals with inter-age group differences, the second part addresses intra-age group differences.

Due to space limitations, a third issue of interest to gerontologists – the extent to which successful aging is mediated through self-esteem – is not covered in this article. Research is beginning to show that self-esteem may be an important factor in health behaviors, coping, and well-being.

Stability and Change in Self-Esteem across the Life Course

Does self-esteem change with aging? Or is it determined by the time an individual reaches adulthood? Does the aging process have a negative or a positive

impact on self-esteem? If self-esteem does change over the life course, is the pattern linear or curvilinear? What theories are helpful in guiding research on these questions? This section describes the theoretical, methodological, and empirical literature on this topic.

Theories Regarding Stability and/or Change in Self-Esteem over the Life Course

The question of whether self-esteem changes with aging can be approached from a variety of theoretical perspectives. These perspectives do not provide a clear set of propositions to be tested; rather, they suggest whether and when self-esteem would be expected to change, and if so, the direction of that change over the life course. The theoretical approaches include (1) personality trait psychology, (2) life span developmental psychology, (3) role theory, and (4) life course theoretical perspective.

Personality trait theories The question of whether self-esteem changes over the life course could be considered within the larger, ongoing debate in gerontology as to whether personality changes with aging. The extent to which personality changes or remains stable is a long-standing question in the social psychology of aging. Thus, it may be instructive to consider self-esteem and aging within this context since many of the methodological and theoretical issues with regard to stability are the same.

Traditionally, personality traits were defined as the tendency of individuals to behave consistently across situations. Traits could be measured only with projective tests or observations of behavior by trained observers. However, contemporary definitions of personality traits were broadened to include cross-situational consistencies in individuals' thoughts and feelings as well. Consequently, researchers were able to obtain reliable measures of traits with surveys and questionnaires in studies with large samples and longitudinal designs.

Contemporary personality theorists most commonly measure traits by making inferences from respondent's self-reports on a number of scaled survey items. That is, the methods used to measure personality became the same as those used to measure self-concept. This enabled the research on personality to be integrated with the research on the self-concept.

While self-esteem refers to the affective or evaluative component of the self-concept, personality represents the cognitive component. Despite this important distinction, many researchers view self-esteem as a personality trait. Since personality traits are assumed to be stable, at least once the individual reaches adulthood, trait theorists would predict that self-esteem would remain stable across the life course.

Life span developmental theories Developmental life span psychology grew out of the work of Freud, Erikson, and Piaget. These theories share the notion that development, due to its biological basis, is universal and occurs in a sequence of stages generally corresponding to age.

Erikson's eight-stage theory was the first to include adult stages of development. During the sixth stage, intimacy versus isolation, individuals are involved in mate selection, family formation, and career development. Once resolved, individuals move on to the seventh stage, generativity versus stagnation, a time when individuals are concerned with productivity, creativity, and guiding the younger generation. During the last stage, ego integrity versus despair, individuals become less concerned with achievement and more accepting of their life as meaningful.

More recent life span developmental theorists suggest a similar sequence of development. Early and middle adulthood are dominated by a concern with the self, power, accomplishments, and control. Conversely, late adulthood is characterized by a reduction in ego concerns and an increase in self-acceptance. Theories of the stages of adult development suggest that aging is associated with a growing acceptance of self and others.

The life span developmental perspective implies that aging, rather than being merely problematic, is also a positive process. Individuals potentially progress from high levels of ego involvement and self-serving activities in early and middle stages of life to high levels of altruism and interiority in late life. These types of developmental changes lead to a less critical evaluation of self. Thus, based on this perspective, one would predict that self-esteem would progressively increase over the life course.

Role theories Sociologists are critical of theories of life span development for ignoring the contribution of social structure to stability and change across the life course. From a sociological perspective, age-related roles are more important than chronological age for a variety of behaviors and attitudes, including self-esteem.

Roles serve as the link between the individual and society. According to role theory, individuals develop a sense of who they are through interaction with others in the variety of roles they play. Because role relationships are relatively enduring and organized, roles can be a source of stability in self-identity. And because roles are closely connected to the norms

and values of society, having roles not only integrates the individual with society, but also makes life meaningful.

Throughout the different stages of life, individuals are engaged in the process of role acquisition, role transition, and role loss. Age can influence, if not determine, role access and egress. During early and middle adulthood, individuals acquire and transition into many new roles, such as occupational, marital, and parental roles. Involvement in multiple roles provides the individual with many opportunities for social rewards and feelings of competence and achievement. Involvement in social roles results in high levels of self-esteem during these stages in the life cycle. However, during late adulthood individuals experience role loss such as retirement, widowhood, empty nest, and declining health. Consequently, individuals are less integrated with society and have fewer opportunities for social rewards and feelings of competence and achievement. Lack of involvement in social roles would be predicted to lead to low self-esteem toward the end of the life cycle.

This is the same prediction that would be made by activity theory. Activity theory is one application of role theory to the elderly. According to activity theory, social interaction is important for the maintenance of self-esteem. Since the elderly lack formal roles and status within the main institutions of society, it makes it difficult for them to maintain a positive self-evaluation. Continuity theory, another off-shoot of role theory used in gerontology, makes a slightly different prediction. It suggests that a reduction in role activity does not lead to a decrease in self-esteem as long as the individual maintains some continuity between past roles and current interests and behaviors.

From the role perspective, there are two additional reasons why self-esteem would be expected to decline with increasing age. First, the youth-oriented culture in which people live has promoted the development of negative stereotypes of the old. To the extent to which older adults believe and accept these negative expectations, they are cast in unattractive roles. This in turn leads to lower self-esteem. Second, rapid technological advances and social change sometimes make it difficult for older adults to keep pace with society.

Life course theoretical perspective Proponents of the life course theoretical perspective argue that any analysis of individuals must take into account the sociocultural and historical context in which the individuals live. Macro-level events such as the Great Depression, major wars, and various social and political movements interact with the micro-level age-graded role transitions of individuals from different birth cohorts. Different birth cohorts presented with the same events may experience those events in different ways. For example, individuals of draft age during the Vietnam War may have experienced the role transitions of graduation, occupational attainment, marriage, and parenthood differently than individuals who were a decade younger. Both birth cohorts lived during the same historical period, yet the effect of the historical period on the major role transitions of members of each cohort was very different.

This interaction between person and situation can have long-lasting effects and can result in different life course trajectories. This would require studies that would compare different birth cohorts across the long periods of time in order to separate the age, period, and cohort effects.

The importance of this perspective for the study of self-esteem is that it suggests that the level of self-esteem for individuals from a particular birth cohort may, due to sociocultural or historical events, start out lower or higher than other birth cohorts. These events may maintain their influence on the level of self-esteem across the life course and act as a source of stability in self-esteem. For example, individuals born during the Great Depression may have lower self-esteem than individuals who were born after it, and this suppression effect on self-esteem may evidence itself across the life course of this cohort. On the other hand, depending on the stage of life during which the macro-level event occurs, and whether additional events occur at later stages of life, the events could be a major source of change in self-esteem. The direction of the change on self-esteem, either positive or negative, would depend on the event and how it interacted with the age-graded role transitions that were experienced.

Methodological Issues in Studying Self-Esteem and Aging

What are the methodological challenges in examining self-esteem across time? Three methodological issues present challenges to those wishing to study stability and change in self-esteem across the life course: (1) research design, (2) measurement, (3) statistical analysis and data interpretation, and (4) population sampling.

Research design The fundamental problem with cross-sectional studies of self-esteem is that maturation and birth cohort effects are confounded. Thus, it is impossible to determine whether age differences in self-esteem actually represent changes in self-esteem

over time or whether they represent cohort differences. In longitudinal designs the same individuals are studied over a period of time, thereby controlling for intercohort differences.

Although longitudinal studies of self-esteem would be a substantial improvement over cross-sectional studies, several issues still need to be considered. The few existing longitudinal studies of self-esteem have focused on younger age groups to the exclusion of older age groups. Further, these longitudinal studies followed their respondents for relatively short periods of time. To adequately study the effects of aging on self-esteem, mature adults should be included for study, and individuals should ideally be followed across several stages of the life course.

However, even longitudinal designs that span several life stages cannot rule out all alternative explanations. In longitudinal studies of single cohorts, age changes would be confounded with the effects of time of measurement. Further, the unique historical experience of the birth cohort under study (described more fully in the section on contextual analysis) and the possibility of selective attrition could also make the interpretation of aging effects in self-esteem ambiguous.

No design can provide completely unambiguous results regarding the stability of self-esteem across the life course since aging, time of measurement, and birth cohort will always be confounded in any design that is used. However, the optimal method for studying self-esteem and aging would be to use a cohort-sequential design. In a cohort-sequential design, more than one birth cohort would be followed over the same developmental span of time but different historical spans of time, in order to separate out the effects of aging, cohort membership, and social/cultural events on self-esteem. Currently, there are no published cohort-sequential studies of self-esteem.

Measurement One methodological issue is the measurement of self-esteem. Because the majority of the literature on self-concept deals with self-esteem, the terms are often (incorrectly) used interchangeably, leading to a lack of conceptual precision. Similarly, researchers also refer to self-esteem by a variety of other terms, such as self-regard, self-respect, and self-confidence. Without clear definitions, measures cannot adequately represent the constructs under study. Many studies develop their own unique measure of self-esteem rather than use standard scales. Not only do researchers fail to use the same instruments, but they also rarely examine the validity or reliability of these one-shot measures. The practice of using different measures generally produces different information about stability and change in self-esteem across the life course, making it difficult to draw conclusions.

Several standard scales are available to measure self-esteem, the most popular among them being the total positive scale from the Tennessee self-concept scales, the Rosenberg self-esteem scale, and the Monge semantic differential scales. The problem with these scales for age-based analyses is that their validity and reliability, although established on young age groups, have rarely been calculated for older age groups. Without these statistics and evidence of factorial invariance across age groups, intercorrelations between self-esteem and age are difficult to interpret. Low intercorrelations may mean there is no relationship between age and self-esteem or, alternatively, that the scales are inappropriate for use with older age groups.

Statistical analysis There are four ways to assess stability or change in self-esteem: (1) structural invariance, (2) correlational stability, (3) mean level stability, and (4) ipsative stability.

Before other types of stability in self-esteem are assessed, it is necessary to establish that there is structural invariance. Structural invariance refers to the stability in the structure, organization, or dimensionality of self-esteem, typically assessed through factor analysis or cluster analysis. Structural invariance is established when the measure of self-esteem displays the same dimensions and relationships among component elements over time and/or across birth cohorts.

Correlation, the most frequently used method for calculating stability, is a measure of constancy or change in an individual's rank order position on self-esteem over time. Pearsonian, Spearman, or Kendall correlation coefficients are computed between measures of self-esteem at different time points for the same group of individuals. These statistics indicate the extent to which individuals retain their position on self-esteem relative to others from one time of measurement to another.

However, there is no set standard for evaluating whether the level of the coefficients obtained actually represents stability. Consequently, a correlation coefficient of 0.50 may be interpreted by some as an indication of substantial stability in self-esteem, while others may interpret it as an indication of substantial change.

Mean level stability is the constancy or change in the group level of self-esteem over time. In longitudinal

designs, mean scores on self-esteem are compared for the same group of individuals between different time points. Attention is paid to increases or decreases over time in both group mean scores and group variances. No change on group mean scores would indicate stability only if there were also no change in group variances. If there were no change in group mean scores but the variance increased, this would indicate increased individual differences in self-esteem. Change in mean level stability can also be assessed using a repeated cross-sectional design. Aging effects for self-esteem are examined by comparing group means on self-esteem for the same cohorts at different times.

As with correlational stability, there is no agreed-upon standard for deciding whether a statistically significant change in mean level scores is actually substantively significant. That is why a measure of effect size that is independent of sample size should also accompany analyses of mean level or normative stability.

Ipsative stability, a measure of intraindividual continuity in self-esteem, is the least frequently investigated. Based on profile analysis, it provides information as to whether an individual's attributes change their relative position over time.

Depending on the method used to assess stability, the results are likely to be different. Stability using one method does not imply stability using another method. Each method provides different information and likely leads to different conclusions regarding stability or change in self-esteem across the life course. Ideally, studies should report results using all the methods and try to explain any inconsistencies that are found.

Population sampling Substantial heterogeneity exists within the populations sampled for studies of self-esteem. Although respondents vary in sociodemographic characteristics, health, birth cohort membership, and so on, the extent to which these factors contribute to stability or change in self-esteem over the life course is rarely considered. Further, cross-sectional studies that examine age differences in self-esteem do not represent the full spectrum of adulthood among their respondents. For example, some studies compare young adulthood to middle adulthood, while others compare the old to the oldest old. Longitudinal studies have not followed individuals for long periods of time. Without the inclusion of respondents from all age groups or the examination of the same individuals across a large number of life stages, studies can lead to incomplete findings regarding the pattern of stability and change in self-esteem across the life course.

Empirical Studies of Self-Esteem and Aging

What empirical evidence exists on the stability of self-esteem across the life course? Over the last three decades there have been literally thousands of studies published on self-esteem. Given the preponderance of research on this concept, it is surprising how few studies have examined the relationship between self-esteem and aging.

Of the studies looking at age differences in self-esteem that have been published in peer-reviewed journal articles, the majority have employed cross-sectional designs, leaving age and cohort effects confounded. Further, most of these studies have focused on childhood and adolescence. Of the handful of studies that included older adults, the findings were inconsistent: some showed an increase, some showed no change, and some showed a decline.

There have been even fewer longitudinal studies of stability or change in self-esteem across the life course. Those that do exist focused on younger age groups to the exclusion of older age groups and followed their respondents for relatively short periods of time. Only five longitudinal studies published in peer-reviewed journals have included middle-aged and/or older adults. Of these studies, most showed a decline during middle and old age. However, no definitive conclusions can be drawn because the length of follow-up in these studies was only a few years. To adequately address the question of stability and change in self-esteem across the entire life course, long-term longitudinal studies are needed.

Predictors of Self-Esteem in Older Adults

Over the last three decades there have been a greater number of peer-reviewed journal articles investigating the predictors of self-esteem in older adults than those examining stability or change in self-esteem over the life course or the mediating effect of self-esteem on well-being. These studies of the correlates of self-esteem can be grouped on the basis of whether the examined predictor variable was (1) demographic, (2) cognitive, or (3) role related.

Several studies have examined whether race, class, and gender influence the self-esteem of older adults. Some studies have found that these demographic factors interact with age or with one another in their effect on self-esteem. For example, lower social class negatively affects self-esteem among the old but not among the young. Receiving public assistance

lowered the self-esteem of older men but not that of older women. In general, older women have lower self-esteem than older men. Regardless of gender, older adults with higher education have a higher level of self-esteem than their less-educated counterparts.

A growing body of literature has investigated whether cognitive style influences the self-esteem of older adults and whether cognitive style interacts with gender in its effect on self-esteem. Identity assimilation refers to a process by which individuals maintain their identity despite age changes, whereas identity accommodation refers to a process by which individuals change their identity as they age. Researchers have found that identity accommodation was negatively associated with self-esteem for both genders; however, identity assimilation was positively associated with self-esteem only for women. Other researchers have found that older adults who are less introspective or have a negative attitude toward aging also have lower self-esteem.

Another group of studies has examined the influence of roles and/or role behaviors on the self-esteem of older adults. Older adults who experienced widowhood, institutionalization, low religious commitment, physical impairment, or a decline in global health tended to report lower levels of self-esteem than those not experiencing these role changes. On the other hand, self-esteem was higher among older adults who felt competent as a worker, had a commitment to the spouse role, and participated in leisure activities, particularly with friends, than those who did not have a commitment to these roles. Retirement did not necessarily lead to a decline in self-esteem.

As a whole, these studies suggest that there are many ways that older adults maintain self-esteem despite role loss and increased infirmity.

Directions for Future Research

Stability and Change in Self-Esteem across the Life Course

Although the vast majority of the studies of self-esteem focus on global self-esteem, researchers recognize that self-esteem is multidimensional. The dimensions of self-esteem are hierarchically ranked based on their importance to the individual. Since self-esteem is multidimensional and hierarchically ranked, specific components of self-esteem may change over time in response to situational or role changes, while other components may remain stable.

The extent to which changes in any of these specific components affect global self-esteem is not known. Components that are central may affect global self-esteem, while changes in other less central components of self-esteem may have little impact on global self-esteem. Thus, self-esteem may incorporate both stability and change.

Future research should examine whether the aging process results in decreased day-to-day instability in self-esteem and how this relates to long-term stability or instability. Self-esteem may fluctuate day to day or from situation to situation but still retain a stable core. The question for future research should be not only whether self-esteem is stable across the life course but also under what conditions it is stable and under what conditions does it change.

Little is known about the developmental, social structural, contextual processes that influence stability and change in self-esteem across the life course. Future research should be directed at studying how the timing and sequencing of developmental maturation, role change, and life events influence self-esteem over time. In addition, research should be conducted on how the sociocultural and historical context affects the self-esteem of different birth cohorts.

In terms of methodology, the ideal study of stability and change in self-esteem would employ a longitudinal cohort-sequential design that examines different cohorts over the same developmental period but during different historical periods. In terms of theory, the ideal study would combine aspects of all theoretical perspectives to allow for the most fully developed examination of self-esteem and aging.

Predictors of Self-Esteem in Older Adults

Future research on the predictors of self-esteem in older adults should continue to examine the possible interactions between age and other demographic, cognitive, and role-related factors. For example, helping others has been found to increase self-esteem among older adults, but this positive outcome was maintained over time only for respondents whose socioeconomic background was high.

Future research should also compare the relationship between primary aging and self-esteem with that of secondary aging and self-esteem. It may be that self-esteem declines only with secondary aging but not primary aging. Self-esteem may remain high among those who experience only primary aging but not the blows of secondary aging, particularly if they are taught appropriate cognitive styles.

See also: Life Course; Life Span Theory; Longitudinal Studies; Personality; Theories of Aging: Psychology; Theories of Aging: Social.

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Self-Concept and Body Image

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Glossary

Body image – Individual's physical sense of self.

Osteoarthritis – Degenerative joint disease.

Photoaging – The damaging effect of ultraviolet rays on the skin.

Sarcopenia – Reduction in muscle fiber associated with aging.

Introduction

A major focus within gerontological research concerns the effects of the aging process on the body's functioning. In view of the extensive research on physical aspects of the aging process, it is somewhat surprising that the psychological implications of these physical changes are as yet relatively unexplored. Investigations of the relationship between physical health and psychological well-being pertain only very generally to the question of how changes in the body affect the individual's sense of self, self-esteem, and ultimately, subjective well-being. Left unanswered are questions regarding more precise links between physical changes that result from aging and the objective and subjective ways that individuals adapt to these changes. Although there is little research and theory on the concept of physical identity per se, it is recognized that the sense of self with regard to physical characteristics is a feature of the self-concept and, furthermore, that satisfaction with the body contributes to overall feelings of self-esteem. The concept of body image holds important promise for understanding these fundamental issues of aging and the self-concept.

Components of Body Image in Adulthood

Most people regard themselves as having completed physical development by the end of their teenage years, but the fact is that the body continuously changes its shape, dimensions, and dynamics up until the time of death. These changes have the potential to alter the individual's physical sense of self, or body image.

The term body image may be thought of in the narrow sense as the mental representation of one's own body and, for example, may be regarded as a problematic area in disorders in which the individual has an inaccurate body image, such as body dysmorphic disorder, or an eating disorder, such as anorexia. Studies of body image identify three central components that make up this sense of the physical self. They are the perception of (1) the appearance of one's own body, (2) competence, or the body's ability to perform tasks needed in daily activities, and (3) physical health or the reflection of the individual's risk of mortality.

Experiences in later adulthood that are relevant to physical identity can take place within a number of contexts of adult life, including relationships with family, the performance of job-related duties, leisure

involvement, and interactions with friends and acquaintances. Events in the outside world may also have relevance, as these influence the individual's ability to function on a daily basis. For example, changes in funding for public transportation can limit the older individual's mobility in an urban setting, further complicating any age-related changes that interfere with self-care and autonomy.

Physical appearance provides important external cues to the self and others. Hair color, skin texture, body weight, body height, and the arrangement of facial features are just a few of the components of physical appearance. Body image with regard to appearance includes the individual's self-perception and appraisal of these outward characteristics. The internal feelings of body competence are based in part on the physical sensations received when the body is applied to particular tasks such as walking, climbing stairs, carrying heavy objects, and being able to see and hear events in the environment. Older adults are theorized to derive their feelings of bodily competence from their ability to engage successfully in such tasks without pain or effort. The third component of body image, physical health, refers to the individual's self-attributions in relation to disease processes. For example, being in constant pain due to arthritis has a negative impact on this component of body image. Fear of the unknown after being diagnosed with a terminal illness can also have a deleterious effect on the individual's bodily self-image. Disease processes seen as posing a threat to life can lead the individual to experience feelings of self-alienation from the body ('why is my body doing this to me?'). Anecdotally, in this regard, individuals often refer to 'my cancer' when talking about this disease. As the cancer has invaded their bodies, it has also invaded their sense of self. On the positive side, for individuals who are fortunate enough to avoid chronic disease in later life, this component of body image can contribute favorably to their overall sense of well-being. They feel vibrant and in control of their destinies.

Normal Age-Related Bodily Changes

Throughout adulthood, individuals experience changes with age in the body that can influence body image through their effects on physical appearance, competence, and health. Clearly, not everyone experiences these changes to the same degree, but knowing that they can occur, even if they do not, can cause the individual's body image to respond accordingly.

Physical Appearance

Looking first at the outward manifestations of aging, changes in appearance occur due to the wrinkling and sagging of the skin, loss of height, and changes in body fat. The skin, in addition to becoming more wrinkled and baggy, changes coloration, particularly on the face. As a result of the process called photoaging (exposure to the sun), dark spots accumulate and small capillaries become more visible on the surface of the face. Fat under the skin diminishes, causing the features to sag, and loss of bone contributes to the shrinking of the jaw. Wrinkles develop particularly as a function of the individual's typical expressions (laugh lines or frown lines), but some wrinkles such as the furrow between the brows develop without any particular instigation, reflecting instead genetic predisposition. Other changes indirectly affect facial appearance, such as loss, shifting, and discoloration of teeth. While all of this is going on, hair becomes more thinly dispersed on the head, its pigmented color is lost, and it may change in texture. Some hairs pop up in unwanted places, such as the ears, chin (in women), and nose. As a contributor to changes in body image, it is difficult to imagine a more potent stimulus than the effect of aging on appearance.

Changes in body build also contribute to the aging of the appearance component of body image. Although there is a total loss of weight beginning in the 60s, typically this net loss is due to a reduction in muscle fiber (called sarcopenia) and an increase in body fat. As body fat increases, it also shifts in its distribution. Subcutaneous fat (the fat under the skin) is reduced and fat around the middle of the body begins to accumulate in the infamous phenomenon known as middle-aged spread.

Competence

Feelings of competence are affected by changes that occur in the body's strength, power, coordination, and ability to have an impact on the environment. The normal aging process results in the loss of muscle strength and aerobic capacity at an average rate of approximately 1% per year. At the same time, the bones become weaker and more brittle as a result of normal loss of bone mineral content. A reduction in cartilage in the joints along with other deleterious changes leads to pain and a loss of joint flexibility. A loss of elasticity in lung tissue translates into the sensation of greater difficulty in breathing and shortness of breath. Within the urinary system, there is also a loss of elasticity in the tissue that composes the bladder, leading to feelings of discomfort. At the level of bodily regulatory systems, there are decreases in the circulating levels of sex hormones in both men and women. These hormonal changes may or not be perceived by the individual, but even if they are not, beginning in middle age there is a recognition that the potential to reproduce declines gradually

(for men) or completely (for women). Other hormonal changes lead to alterations in sleep patterns and a decreased ability to tolerate extreme heat or cold. Individuals vary considerably in the rate at which they experience these changes, but at one point or another, the aging person is likely to encounter most, if not all. Changes in body image relevant to the body's competence would, in this sense, seem theoretically to be virtually inevitable.

Although cognitive functioning is technically not a component of body image, it may be thought of as a contributor to the individual's feelings of competence. Beginning in middle age, adults begin to worry that they are losing their memory, even if they are not experiencing objective declines. Exaggeration of memory declines are most likely related to feelings of distress and a tendency to exaggerate or worry. It is not until later adulthood that memory changes reach significant levels in the laboratory, but from the standpoint of daily experience, the older individual may become convinced that Alzheimer's disease will soon follow these mental slips. Frustration with these cognitive changes may cause the aging adult to feel both hopeless and annoyed. Difficulties in driving ability may contribute further to changes in the individual's feelings of cognitive competence.

Health

The development of chronic illness in later adulthood can lead the aging person to feel disengaged from his or her own body when malfunctions in important functions accumulate, and, even worse, when it seems as though these malfunctions threaten to cut short the individual's life. Although not considered a function of normal aging, there is an accumulation of chronic disease such that the majority of older adults suffer from life-threatening illnesses, such as heart disease and cancer, or painful conditions, such as arthritis.

The functioning of the cardiovascular system is an important influence on the individual's feelings of well-being and identity. Many individuals interpret changes in this system, whether due to disease or to normal aging changes, as significant for the viability of the body or its ability to sustain life. Feelings of mortality are perhaps most closely linked to this system. All adults know that the efficiency of the cardiovascular system is essential to life, so threats to the integrity of this system are perceived as highly dangerous. Awareness of reduced cardiovascular efficiency can therefore serve as a reminder of one's own personal mortality.

In the normal aging process, fat and other substances accumulate in the walls of the arteries throughout the body. In the disease known as atherosclerosis, these deposits collect at an abnormally high rate, to the point that they substantially reduce the width of the arteries. Many people live with atherosclerosis and do not encounter significant health problems. However, the progressive buildup of plaque that occurs with this disease may eventually lead to partial or total blockage of the blood's flow through an artery, causing death or severe impairment. Changes in the arteries associated with atherosclerosis are thought to be due to the damaging effects of hypertension, a condition in which blood pressure is chronically elevated. Although death rates due to heart disease have gone down dramatically in the past 20 years, it is still the case that these are major killers among this age group. Together, heart and cerebrovascular disease accounted for 40% of all deaths in people over the age of 65 in the United States in the year 2002. Cancer is the second leading cause of death among older adults and is one of the most feared forms of disease throughout the adult years. In 2002, it was estimated that about 1.3 million Americans received a diagnosis of cancer and that about 8.9 million were living with the disease. Most cancers become more prevalent with increasing age in adulthood because age is associated with greater cumulative exposure to harmful toxins (carcinogens) in the environment.

Arthritis is the most common chronic illness affecting older adults; the majority of older adults who suffer from this disease are victims of osteoarthritis, a painful, degenerative joint disease that often involves the hips, knees, neck, lower back, or the small joints of the hands. Osteoarthritis typically develops in joints that are injured by repeated overuse in the performance of a particular job or a favorite sport or from obesity and the carrying of excess body weight. Eventually, this injury or repeated impact thins or wears away the cartilage that cushions the ends of the bones in the joint so that the bones rub together. The articular cartilage that protects the surfaces of the bones where they intersect at the joints wears down, and the synovial fluid that fills the joint loses its shock-absorbing properties. Joint flexibility is reduced, bony spurs develop, and the joint swells. These changes in the joint structures and tissues cause the individual to experience pain and loss of movement.

Normal aging is associated with loss of bone mineral content due to an imbalance between bone resorption and bone growth. This loss of bone mineral content is called osteoporosis when it reaches the point at which bone mineral density is more than 2.5 standard deviations below the mean of young White, non-Hispanic women. It is estimated that 10 million individuals in the United States have osteoporosis, 80% of them women. Women are at higher risk than

men because they have lower bone mass in general, and menopause, with its accompanying decrease in estrogen production, accelerates the process. White and Asian women have the highest risk, and Blacks and Hispanics have the lowest. In addition, women who have small bone structures and are underweight have a higher risk than heavier women. Osteoporosis differs from osteoarthritis in that there is no pain associated with the condition itself. However, the weakening of the bone associated with this disease significantly increases the individual's risk of fracture in a fall and may even increase the risk of fractures that in turn cause the individual to fall.

Prevention and Compensation

The changes described thus far seem to present a somewhat pessimistic view of age-related changes in the body. However, not everyone undergoes these changes at the same rate, and many of these changes can be compensated or prevented. Preventative measures include daily use of sunscreen (SPF 15 or higher) and application of moisturizers and creams containing alphahydroxy acids and antioxidants. Individuals can compensate for these changes in the body's appearance through exercise and regulation of diet. Strength training and aerobic conditioning are the primary forms of exercise that can serve to minimize the effect of normal age-related changes in the body.

In addition to the fact that people vary in the rate of change over adulthood, compensation and especially prevention play important roles in minimizing the effects of aging on the body, and hence, body image. For example, losses in aerobic capacity and muscular strength can be cut in half by participating in regular aerobic exercise. Exercise along with dietary control is also an important preventative measure for reducing the risk of heart disease in middle-aged and older adults. Lifestyles factors also contribute to cancer risk; the three greatest risk factors for the development of cancer are exposure to the sun, cigarette smoking, and lack of control over diet. By controlling exposure to these risk factors, middle-aged and older adults can control their likelihood of developing cancer. Finally, there is relatively little that the aging individual can do to prevent osteoarthritis other than to avoid placing excessive strain on the joints. Treatment for osteoarthritis takes the form of a medical intervention involving pain relief or, in cases of extreme joint damage, partial or total replacement. Osteoporosis can be prevented through a number of routes, including taking calcium and vitamin D, engaging in resistance training, and avoiding high-risk behaviors such as smoking.

Memory losses can be compensated by mnemonic strategies, and changes in information processing that would affect decision making, problem solving, and intelligence are generally more than offset by increased experience. Through the actions they take, individuals can slow down or accelerate the aging process. In the case of physical appearance, for instance, individuals can alter the rate at which they experience photoaging, the damaging effect of ultraviolet rays on the skin. It is well known that adults who use preventative measures (including sunscreen) show a slower rate of facial wrinkling than those who do not. Therefore, one of the most significant outward signs of aging can be slowed through actions taken by the individual. With regard to changes within the body, there is a wide range of preventative actions that adults can take, starting in young adulthood and continuing throughout even the oldest of ages. The most successful of these is aerobic exercise. There is now a convincing array of findings testifying to the benefits of active participation in an exercise program. In addition to its effects on the body, involvement in exercise can promote a positive sense of self-esteem. A sense of self-efficacy can develop as the result of exercise participation, which can further enhance the older individual's self-perception of physical attractiveness. The effects of exercise, among other preventative measures, therefore extend to the area of physical health and chronic disease. Thus, through preventative measures, individuals can to some degree control the rate at which both aging and disease progress and can maintain a positive (i.e., healthy and competent) internal body image.

Changes in Body Image and Their Relationship to Psychological Well-Being

The aging process presents a particular challenge to the maintenance of a stable physical identity over time. Events caused by the physical aging process present challenges that are qualitatively different from other experiences in adulthood that are of a more transitory or fleeting nature. An unpleasant encounter in a chance meeting with a stranger that reflects unfavorably upon one's social identity may be dismissed as not having much personal relevance. If this encounter is of a one-time nature, its potential significance to identity will fade with time. Aging, however, is a process that does not fade with time. The changes that occur as a result of the aging process remain present and may in fact grow with importance as the individual must find ways to integrate them into identity throughout adulthood.

Thus, the aging process has the potential to affect all components of body image – appearance, competence, and health. Many adults feel these changes are incompatible with their sense of who they are. Indeed, they may feel that the aging of their bodies has resulted in only superficial changes and that they have really not changed at all on the inside. However, at the same time, aging brings with it the certain knowledge that the body is not functioning the same way it did when the individual was younger. Thus, there is a distinction that needs to be made between the sense of identity in terms of the outward self and the inward sensations in the body.

Adding to the changes within the individual is the impact of social attitudes toward the aging of the body. Society's definitions of the desirable attributes of men and women present significant threats to body image in later adulthood. For women, social attitudes that aging women are unattractive can lead to the development of a negative body image with regard to appearance. It is indeed difficult for aging women to avoid the barrage of advertisements for anti-aging products that promise to erase the effects of aging. For men, aging may pose a threat to body image with regard to feelings of competence. Physical strength is valued as a male attribute, and therefore loss of muscle strength and agility would be perceived as a threat to this component of body image. For aging individuals of both sexes, social attitudes toward health and illness can erode this dimension of body image. Portrayals of aging individuals with long-term chronic illnesses that cause pain, suffering, and prolonged dependence on caregivers heighten the fear of dying from a long-term disabling illness. Similarly, media portrayals of older adults as suffering from Alzheimer's disease and thus being mentally incompetent further prey on the fears of older adults that they will lose their dignity and independence. Self-acceptance and a positive body image across all domains are thus difficult to achieve for men and women, but for different reasons.

With the many changes that seem to occur either inevitably with age or as a result of disease processes that are more probable in later life, then, it would seem as though individuals who maintain that they have not changed even though they clearly have may be living in a world of unreality. However, there may be advantages to maintaining the internal distinction between self-identity (who I am) from bodily identity (what I am). Aging adults can avoid what might otherwise turn into a hopeless pessimism toward the future. When living in Western society, which treasures youth and beauty, such a self-protective mechanism holds a number of potential advantages. If bodily identity were allowed to dictate self-identity, there would be less incentive for the aging individual to take actions to slow down, prevent, or compensate for normal age-related changes in physical functioning.

Previous research has shown that those aging adults who maintain high levels of subjective well-being are able to distinguish between the way they feel about the self and the way they feel about the body. For example, in a study of 242 men and women ranging from 40 to 95 years of age, it was found that older women who mentally discounted the extent to which their bodies were aging, particularly with regard to appearance, had higher levels of self-esteem than women who focused on age-related bodily changes. Thus, not thinking about the meaning of age-related bodily changes seems to be a favorable way of preserving self-esteem. This does not necessarily mean that denial is the optimal strategy to adapt to a changing body. A good case in point is that women who fail to recognize that osteoporosis increases their chances of falling can benefit from greater awareness of the reality of their health risk. Similarly, although being overly preoccupied with thinness can lead women to develop maladaptive body images and related psychological disturbances, women who are well above normal weight are at risk for chronic diseases. However, acknowledging without giving great thought to the psychological meaning of changes seems to serve a positive function. This process may be particularly important as a way of insulating the older adult woman from the bias and stereotypes she faces in society regarding the attractiveness and desirability of aging females.

Managing to avoid viewing the self as aging may also help older individuals maintain their motivation to exercise. If their bodily self-concept becomes overly negative, they may avoid taking the measures described previously that can help offset some of the deleterious changes with age due to a belief that the benefits of exercise are beyond their reach. Conversely, if they feel that it is worthwhile to exercise and then act on this belief, their body image with regard to competence can be enhanced and, ultimately, so can their self-esteem.

Although men may be less likely to suffer from the negative effects of aging on body image with regard to outward appearance, they may be more vulnerable to the effects of aging on feelings of bodily competence and health. Consequently, they may lose the advantage they have over women during earlier years of adulthood in the extent to which their body image is favorable. One area in particular in which older adult men may be particularly vulnerable is that of sexual functioning. Men who experience sexuality as

an important part of their physical identity and who are unaware of the normal effects of aging on sexual function may place themselves at risk for developing secondary impotence, a condition that involves erectile dysfunction resulting from psychogenic rather than physical causes. Because they are not used to accommodating, when they have an occasional episode of erectile dysfunction, they are unable to use this process of adjusting to change. The episode leads them to conclude that they have lost their potency.

Despite the threats to body image from the aging process, it does appear that the majority of older adults manage to separate the who from the what and that body image improves rather than worsens in later adulthood. In one cross-sectional study of over 300 women ranging from 20 to 84 years of age, there were no age differences in body dissatisfaction, but measures of bodily preoccupation, anxiety, and disordered eating were lower in older age groups. Another cross-sectional investigation of 123 young, middle-aged, and older adult women using the Multidimensional Body-Self Relations Questionnaire (MBSRQ) found no age differences in satisfaction with areas of the body and lower scores among the oldest cohort in preoccupation with weight even though these women had the highest reported body mass indexes. It is possible that older adults have become immune to the evidence presented by their own bodies within the social context that they are losing (as socially defined) their attractiveness, strength, and health.

By contrast, middle-aged individuals are more sensitive to fears of aging than the older adults who are actually experiencing the effects of the aging process. In addition to the possibility that aging brings with it a more relaxed and accepting view of physical changes is the idea that the current cohort of older adults never was as concerned about their bodily functioning and appearance as the current cohort of middle-aged individuals. The Baby Boomers are reaching middle adulthood at a time in history when youth and beauty are revered more than ever. Furthermore, this generation has dominated the social and cultural landscape since their coming of age in the 1960s. Having defined social standards of the desirability of youth, it may be particularly hard for this generation to accept the fact that changes happen within their bodies due to forces outside their own control. On the other hand, current cohorts of middle-aged individuals, at least those with higher levels of education, have embraced the values of exercise and dietary control. Therefore, they may actually be less likely to experience the challenges to identity presented by changes observed among historically less fit older cohorts.

In summary, the construct of body image bears central significance to the life of the aging individual. The ways that individuals adapt to the alterations in the internal and external structures of the body involved in the aging process are important mechanisms for promoting the individual's ability to adapt to the changes in health and functioning associated with aging. Current evidence suggests that the majority of older adults have indeed found ways to live comfortably inside their aging bodies.

See also: Exercise and Physical Activity; Life Satisfaction; Psychological Well-Being; Self Esteem; Theories of Aging: Psychology.

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Self-Regulation, Health, and Behavior

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Glossary

Feel Good Heuristic – Feeling good serves as an indicator of health.

Self-Regulating Model – Model indicating that health risks are likely to be experienced in response to somatic changes, and that symptoms experienced speed the seeking of health care.

Introduction

The title of this article, Self-Regulation, Health and Behavior, implies two broad themes. First, that behavior is a determinant of health outcomes, and second, that individual, self-regulation processes underlie health behaviors. Our goals for the first theme include spelling out specific examples of known causal links between behavior and health, the onset of chronic illness in particular, point to some of the pathways involved in disease onset, and discuss the role of health behaviors in the elderly. For the self-regulation theme we address a number of the mechanisms that underlie self-management practices. We show that self-regulation practices can be helpful or harmful to health depending upon the validity or match between the biology of disease and the perceptions and beliefs about specific diseases and the factors responsible for the future risk and control of existent illness. We emphasize the role of contextual factors, particularly the presence or absence of disease and the nature of the experience created by disease, in moderating the self-management process.

Behavior and Health Outcomes

Genes and Behavior

The current emphasis on genes as the cause of chronic disease may seem inconsistent with the estimate by the Institute for the Future that over half of the variance in health outcomes is determined by behavior. Individuals with common genetic risks may, however, manifest disease onset at very different times in life, since environmental factors and behavior play important roles in gene expression. Behavioral factors can affect disease risk through three pathways: (1) altering physiological processes that affect gene expression and the manifestation of inherited risks, (2) creating genetic mutations that generate disease, and (3) producing physiological changes that have direct effects on the disease process or by weakening or inhibiting somatic defenses. It is not clear that this view of gene–environment interaction has entered the public mind, though statements that genes are not sufficient causes for disease

can be found in the science section of daily newspapers. For example, cigarette smoking affects all three of these pathways, increasing the lifetime risk of chronic illness. The 4500 or more inhaled toxins produced by the combustion of the tobacco and paper in a cigarette can accelerate the mutation of DNA in lung tissue and disrupt mechanisms for reconstructing DNA damage, and this damage proceeds well outside of conscious awareness. Smoking also reduces pulmonary capacity, and the toxins stimulate processes involved in damaging coronary arteries. While individuals may be aware of some of these changes, they may not attribute them to smoking or may not see them as serious even if their attributions are correct. Thus, smoking is a risk factor for many of the 200 or more types of cancer and a multiplier of risk for cardiovascular and pulmonary disease. Obesity, often used as a marker for disease risk, is a product of caloric intake exceeding caloric consumption and is typically due to high quantities of junk foods in the diet and lack of physical activity. Dietary issues are complex, and disease risk varies with the intake of specific nutrients. For example, fats affect gene expression, some, e.g., omega 6 fatty acids, creating and others, e.g., omega 3, reducing risk of prostate cancer. Physical activity or exercise reduces risk across a wide spectrum of diseases; indeed, it can improve the ability to perform activities of daily living in women over 70 years of age. The extent to which diet and physical activity can impact rates of chronic disease is clear from the current epidemic of obesity and the appearance in teenaged adolescents of type 2 diabetes, a disease formerly exclusive to the elderly.

Life Span, Disease Risk, and Disease Management

The interaction of behavioral factors with genetic variables in the development of chronic illnesses highlights the life span, developmental aspect of these diseases. Type 2 diabetes and cardiovascular diseases develop over years and decades; they do not occur all at once. Deficits in mechanisms for transporting and storing glucose, glycogen, and lipids in cellular depots, rather than circulating at high levels in the bloodstream, lead to the gradual accumulation of cellular damage and the arterial occlusion underlying cardiovascular disease. The high level of blood sugar in type 2 diabetes destroys the neural networks for vision and sensation in the feet and kills the capillary-sized vessels in the kidney essential for filtering the blood; blindness, foot amputation, and kidney loss and dialysis or death are the consequences of each of these collateral effects of uncontrolled diabetes. The picture is similar for cancer. Clinically detectable disease is the end product of a sequence of changes in cellular processes, and the escape or metastasis throughout the body involves interactions of death-defying cancer cells with the vasculature. These changes take place over years and decades, and while some of these changes are partially reversible, many are not. Accumulating evidence strongly suggests that the fetal environment and the experience of infectious disease early in life can affect vulnerability to coronary disease (e.g., elevated blood pressure) and other chronic conditions at far later times in life.

Lifestyles are critical factors for disease risk and therefore for disease prevention. Whether we smoke cigarettes and use drugs, what we eat and drink, and whether we are immobile in front of TV and computer screens, driving, and taking elevators, or walking, climbing steps, and exercising are major influences on whether disease risk is high or low. If patients are non-adherent to treatment, fail to self-regulate, and take medication to control blood pressure or insulin to lower and maintain acceptable levels of blood sugar, they will risk stroke and cardiovascular disease and the complications of diabetes, i.e., blindness, kidney loss, and foot amputation.

Behavior and Health Outcomes in the Elderly

The young rather than the elderly are often seen as the appropriate target for improving health outcomes via behavioral change. The idea that the young and not the elderly are the appropriate target for health behavioral change reflects three beliefs. The first, and probably most important, is the belief that implementing healthy behaviors will not lead to reductions in disease or improvement in health among elderly populations because the damage has already been done and is irreversible. Second, as research suggests, the elderly are already more actively engaged in some health promotion behaviors and therefore are not in need of intervention. A third is the belief that elderly individuals are not interested in making behavioral changes, a belief consistent with the frequently reported finding that elderly persons are difficult to recruit into behavioral interventions.

In reality, health behaviors are an integral component of quality aging, influencing disease progression, disease onset, and quality of both mental and physical life throughout the life span. Maintaining activity levels, including exercise, is suggested to protect against Alzheimer's disease, controls weight, acts to maintain or increase social support, which is associated with increased longevity and quality of life in the elderly, improves functioning, prevents myocardial infraction, and is an effective treatment for

depression in the elderly. Similarly, eating a low-fat diet is as effective for reducing rates of coronary disease and all-cause mortality among those in their the fifth and sixth decades as it is among younger populations. And while rates of some health behaviors do appear to be higher in elderly populations, we are nowhere near an optimal level or universal compliance. For example, Myer *et al*. used yearly mailings for 2 years to encourage fecal occult blood tests to detect colon cancer. In the first year both the young and old had a 50% response rate; in the second year only 25% of those under 65 years of age responded, while the same 50% of those over 65 responded. While it is impressive that the elderly population maintains their screening habits, it is disturbing that 50% of those in the highest risk group did not get screened. While this study highlights the need for interventions in the elderly, it also provides evidence against the idea that the elderly are resistant to change and unmotivated to participate in interventions. It is our belief that an incomplete understanding of the self-regulatory process among the elderly often leads to assumptions of disinterest or poor motivation. Interventions that take into account a complete understanding of the self-regulatory process will be able to target the unique motivations of the elderly.

Self-Regulation and the Control of Disease and Disease Risk

The biobehavioral picture is clear: our lifestyles, or how we regulate our systems, affect the risk of future disease and progression and control of current disease. But is there a good match between the system underlying self-regulation and the biological progressions involved in disease risk and progression? Although we are far from the final answer to this complex question, we can see the outlines of an answer by comparing what we know about the self-regulative process and the biology of disease risk and progression. To address this large question we first overview the self-regulation process; i.e., we identify the large sets of variables that shape health behaviors and point to some problems in the interpretation of research findings, focusing on the uniformity of the underlying model across a variety of contexts, including disease prevention and self-regulation of distinct illnesses. Next, we describe how the general model has been and remains to be specified to understand the factors affecting the initiation and maintenance of health behaviors in three health contexts: (1) symptomatic illness experience (coronary conditions such as congestive heart failure [CHF] and myocardial infarction), (2) asymptomatic illness experience (hypertension and type 2 diabetes), and (3) chronic conditions experienced as episodic attacks (e.g., asthma). In these examples we make clear how contextual factors moderate self-regulatory associations; explain how action plans, monitoring, and heuristics are integral and used within the system; and discuss how the same model can underlie a diverse set of situations. Our examples focus on applications among the elderly.

The Self-Regulation Process

Cognitive and emotional factors, their interactions, and the personal and social contexts in which these factors operate shape general lifestyles and the specific behaviors that regulate disease threats (see **Figure 1**). Cognitive factors, the perceptions and beliefs about disease threats, the behaviors for managing threat, and plans for action, are the factors most closely linked to behaviors that create and/or reduce risk. These factors include our perceptions and beliefs about (1) the disease, i.e., the representation of a disease threat, (2) the strengths and vulnerabilities of the self, or its disease and health identities, (3) the behaviors for controlling disease threats and the representations of specific procedures for promoting health and controlling disease, (4) the heuristics or rules of thumb that raise and answer questions about the meaning of somatic experience, (5) action plans for the implementation of specific behaviors, and (6) the criteria for monitoring and evaluating the effectiveness of procedures for reducing the proximity and magnitude of threat or for maintaining self-identity.

Emotional factors, including the person's emotional traits, e.g., whether she or he is an anxious, depressed, or hostile person, and emotionally laden beliefs, e.g., fears of specific diseases such as fears of cancer, heart disease, or asthma and fears or concerns about specific behaviors and treatments, e.g., fear that antidepressant medication is addictive, interact with cognitive factors in affecting health behaviors. Contextual factors, beliefs about the self (beliefs about the vulnerabilities and strengths of the self) and the social and cultural context, can have both direct and indirect effects on health behavior, the indirect effects due to the role of contextual factors in moderating or shaping specific cognitive representations and emotional reactions to both disease threats and behaviors and plans for threat control.

Figure 1 provides a simplified picture of the large array of contextual, individual, emotional, and illness-specific factors affecting health behavior. Just as there are multiple pathways to disease, there are

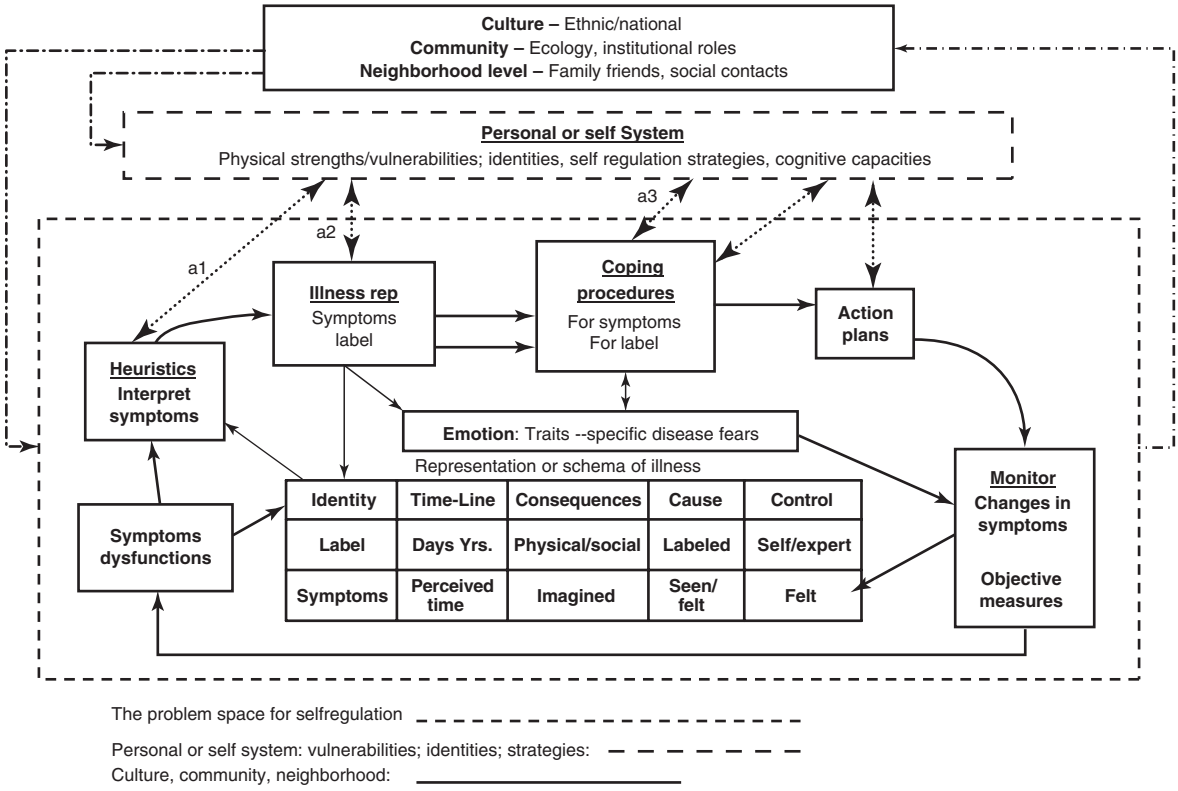

Figure 1 The dynamic feedback process (from the interpretation of symptoms by heuristics through coping procedures to monitoring outcomes) is represented in the problem space for self-regulation, as is the representation or schema of illness and treatment, as is emotion and disease-specific fears that arise from and affect the ongoing appraisal process. The focus of problem-solving activity, the risk of illness or its presence, is nested within the personal or self system, and self-perceptions of specific vulnerabilities and strategies for managing threats affect the problem-solving process and are influenced by the outcome of the process: the relationship is bi-directional though likely stronger from the self to the problem space. Finally, both are nested in social and cultural context.

multiple pathways to specific behaviors. Empirical studies to identify and test the effects of specific pathways from contextual or cognitive factors to a health behavior typically focus on a limited set of factors within two or more of the broadly defined categories of illness representations, procedures for self-management, and/or action plans. It is extremely important to recognize that the illness or treatment representations, action plans, and emotional factors affecting health behavior will be modified by contextual factors including the personal makeup of the participants (e.g., age, educational level) and by social and institutional contexts. An often overlooked factor is the illness threat at the focus of self-management; it too is a contextual variable. For example, causal beliefs contribute to variation in health behaviors for prevention and control of type 2 diabetes, a disease that is perceived to be caused by multiple factors, but make little contribution to variation in health behaviors for the prevention and control of multiple sclerosis, a disease that is widely understood to be inherited.

The variation of models across contexts can lead one to believe that it is impossible to generate a common theory for a diverse range of health behaviors when the difficulty resides in the need to conceptualize and assess the moderating factors that alter the degree to which specific variables affect the behavior under study. An important example of a moderator is whether the threat of illness is present or anticipated. It has been argued that different models are needed to account for actions taken in the presence of symptoms of a suspected or diagnosed disease, so-called illness behaviors, and behaviors taken to avoid health threats in the absence of current illness, so-called health behaviors. Self-regulatory approaches argue that the same system underlies both illness and health behaviors and that the absence or presence of disease, knowing one is sick, and experiencing symptoms of sickness are critical moderators affecting the structure of the underlying behavioral system. In short, the models for illness and health behaviors differ because of differences in context, since different contexts activate different factors in the self-regulatory process that underlies and is common to both types of behavior. The analysis of behavioral models for specific conditions clarifies these general assertions.

Health Behavior in the Prevention and Control of Specific Threats to Health

To illustrate the continuity between the processes underlying behaviors for prevention (health behaviors) and treatment or disease management (illness behaviors), we next examine self-regulation processes in three contexts: in the presence of illness and its symptoms, in the presence of illness but the absence of symptoms, and in the absence of both diagnosed disease and symptoms. Each presents a context moderating the specific variables operating in the underlying self-regulating processes affecting the behaviors involved in the control of one or more health threats.

Self-Regulation and Symptomatic Illness Experience

Although they can occur at all ages, cardiovascular diseases such as hypertension, myocardial infarction, and congestive heart failure are chronic conditions with highest incidence and prevalence in later life. For men, the incidence of myocardial infarction increases gradually from 7% per annum in the fifth decade of life to 22% in the eighth decade of life. The incidence for women is lower overall than for men, but it too rises with age, peaking about a decade later than for men. As stated before, smoking, junk food diets high in fat, and genetic vulnerabilities are interacting risk factors. And given the comorbid relationships among diseases, junk foods and diets high in sugars elevate the risk for diabetes and diabetes further increases the risk for cardiovascular disease.

A basic proposition of the self-regulation model is that health risks are likely to be experienced in response to somatic changes, i.e., to the meaning assigned to symptoms, and disruptions of physical function. Chest pain, problems breathing, and sweating fit the rules of thumb, i.e., the heuristics that interpret these symptoms as signs of cardiovascular disease, and connect the symptom experience to an illness representation of cardiac disease (see **Figure 1**). When these symptoms are experienced they speed the seeking of health care. The self-regulation processes underlying these interpretations and care-seeking behaviors are moderated by a contextual factor, the individual's gender, affecting behaviors that increase risk of death. Because the incidence of coronary disease in women peaks a decade later (seventh) than for men (sixth), and because its symptoms overlap with symptoms of emotional upset (anxiety and depression) that are more common in women, women often mistakenly perceive these symptoms as signs of emotional upset, as do the practitioners diagnosing and treating them. The result is delay in care seeking and delay in the receipt of critical treatment in comparison to men reporting the same symptoms. Three aspects of the self-regulation theory are supported by these findings: heuristics (location and pattern) give symptoms meaning (represented as heart attack) and the meaning motivates behavior (care seeking). And gender can moderate the meaning: the symptoms are attributed to emotional distress in women who delay care seeking.

Self-regulation does not stop with diagnosis and treatment; it continues during rehabilitation and with (presumably) full recovery. Exercise and dietary changes, of determined amounts and carefully monitored, are lifestyle changes integral to rehabilitation. But not all patients participate. Physical activity can create symptoms, and ex-patients who interpret these symptoms as indicators of cardiac risk are unlikely to participate and drop out if they do participate. Simple interventions that provide heuristics for differentiating and redefining posttreatment symptoms as signs of healing facilitate a return to rehabilitation. Self-regulation theory also makes the interesting prediction that individuals who are asymptomatic prior to heart attack will be less likely to engage in rehabilitation posttreatment. This prediction is based on the assumption that treatment and rehabilitation are experienced and understood as beneficial when they result in the removal of symptoms and improvement in function. If, however, an individual experiences neither symptoms nor functional disruption prior to treatment, she or he will experience no posttreatment benefit. Indeed, it will be the treatment, such as bypass surgery, that will be experienced as the source of symptoms and dysfunction. In short, the individual has experienced no gain and is in the same state of lack of awareness of somatic risk posttreatment as he or she was pretreatment, undercutting the motivation for rehabilitation. This hypothesis is now being tested in multiple diseases by investigators in Zurich.

Can we support our claim that the same self-regulation approach can account for behaviors to prevent cardiovascular disease and that it is relevant to health behaviors and not just illness behaviors? The presence and experience of diagnosed disease is clearly a major moderating variable; it can motivate major changes in health behaviors. For example, after a heart attack, smokers are five times more likely to quit. The presence of disease provides powerful evidence of the individual's vulnerability motivating behavior perceived as effective for preventing recurrence. When disease is absent, we can expect that a wider range of variables will create the perception of risk that motivates action. Symptoms, however, are

not out of the picture; that they are still at play is evident by the number of visits to emergency rooms and by individuals experiencing chest pains and other symptoms attributed to heart disease. An individual does not need a personal history of coronary disease to interpret symptoms that fit the location and pattern of cardiovascular disease, and these individuals are frequent visitors to emergency rooms. Emergency room use is a health behavior that reduces a somatically generated sense of threat of heart attack. These patients appear to have a disease-specific fear, perhaps based upon a history of exposure to people with cardiac complaints, and they are not overly fearful of non-cardiac symptoms. Symptoms can motivate protective behavior in individuals with no personal disease history who have a disease-specific fear of coronary disease (see **Figure 1**).

Self-Regulation with Asymptomatic Disease and in the Absence of Disease

There is a relative scarcity of published research on self-regulation processes and health behaviors among elderly individuals in the absence of symptoms and/or a diagnosed or suspected disease. Areas with a rich array of studies, e.g., diet, exercise, and smoking cessation, generally focus on participants less than 65 years of age. The dearth of studies reflects difficulties in the recruitment of healthy elderly, a problem highlighted in the randomized trial of benefits of aspirin conducted in the Northwest region of the Kaiser health plan. In this study conducted by Boles et al., a highly skilled team of investigators sought recruits from the 47 453 individuals over 65 years of age in the Kaiser catchment: 31% of the sample was eliminated at the outset due to a history of cardiac problems and another 10% was participating in other studies. Carefully constructed recruitment material was then mailed to 3600 of the 27 947 remaining healthy individuals in the recruitment pool. The final result of the mailing and phone calls was the randomization to aspirin and placebo of 117 of the 347 elderly who indicated an interest in participation. Two factors were responsible for this outcome. Most elderly have multiple chronic conditions, so their self-regulative processes occur under an illness framework; and most are not interested in participating in research, which was true for the vast majority of the 3000-plus non-responders in the aspirin trial. Boles et al. persuaded 32 of their disinterested, healthy elders to participate in focus groups and discovered that the elderly were wary about participating in trials, did not want to take a placebo or an aspirin, and were uninterested and wary of changing what they were now doing: they were in good health and saw no reason to change direction.

The experience of these investigators is not dramatically different from efforts to recruit for studies of exercise, e.g., stretching and/or walking programs. In the absence of a diagnosis or symptoms, critical triggers of self-regulation processes, there is little incentive to enter a behavioral study. The actual presence of symptoms of disease is not essential, however, for engagement in studies of behavior change. Objective indicators such as difficulties in managing blood sugar loads, indicating risk of diabetes, can serve as a context for recruitment and the activation of self-regulation processes that lead to behavioral changes that reduce the shift from risk to active diabetes. Indeed, the reduction of diagnosed disease is greater for behavioral change than medication. The cognitive-behavioral techniques involved in maintaining self-regulative activities (e.g., 16 direct contacts and numerous phone calls) were, however, far more intensive than could be achieved in the vast majority of real-world practice settings. The absence of studies providing detailed views of the self-regulative processes among healthy elderly is somewhat compensated for by what can be learned from studies of self-regulative processes in studies of management of conditions that are asymptomatic or episodic.

Asymptomatic and Episodic Conditions

Self-management for asymptomatic and episodic conditions allows us to view some of the processes that are involved in primary prevention, i.e., behavior in the absence of disease. These studies highlight three issues: (1) symptoms and emotions are used as indicators for health when they are not; (2) symptom-free intervals are treated as disease-free periods for episodic conditions; and (3) monitoring objective indicators can supplant subjective cues when coupled with behavioral controls.

Hypertension and Diabetes: Using Symptoms When None Exist Studies of hypertension show how people rely on experiential cues as initiators of self-regulation. Hypertension is asymptomatic, and although 80% of the hypertensive patients in Meyer et al.'s 1985 study, most of whom were elderly, agreed that "people can't tell when their blood pressure is up," 92% said that they could tell for themselves. They reported the typical array of symptoms, warm face, tension, etc., as indicators, and 70% of the patients who believed that their medication reduced symptoms were adherent compared to 30% of patients who did not see an effect of medication on their symptoms; thus, 70% of the latter group did

not adhere to treatment. An additional problem for medically correct management arises when patients tell physicians that they use their symptoms to monitor blood pressure; 9 months after beginning treatment 60% of these patients had left treatment! Discrepancies between practitioner and patients undermine treatment.

There is also substantial evidence that individuals use symptoms to motivate behaviors for diabetes that may be maladaptive. Although elevated blood sugar provides few if any somatic cues, there are indications that diabetics use their subjective states as signs of control: if they feel good, they assume they are in good control. Although it is nice to feel good, positive feelings are inadequate indicators for diabetes and for hypertension. The positive feeling heuristic is flawed, as elevations in both blood sugar levels and blood pressure can lead to mild euphoria. Positive feelings may be reassuring because they contrast with the negative symptoms that are clear signs of excessively low blood sugar, severe hypoglycemia, which can lead to unconsciousness and death. Fear of hypoglycemia can be assessed, and as expected individuals reporting high levels of this specific fear also have blood sugar above recommended levels.

The challenge for effective self-regulation for both hypertension and diabetes is to transition from subjective cues, symptoms, and moods to objective indicators: blood pressure and blood glucose readings. Relatively little is known, however, as to how this transition can be created. The substantial success in reducing diabetes for at-risk individuals reported by the Diabetes Prevention Project was extremely labor intensive. It is clear that monitoring and connecting objective measures such as blood glucose readings to specific health behaviors may be sufficient to lead to better self-management in asymptomatic patients. The key will be to connect the objective indicators to daily life activities, and gradually adjusting those activities so their effects are seen in objective blood sugar levels that approach desired targets, e.g., reductions in meal size, not putting sugar in coffee or tea, and taking the stairs instead of using the elevator. Many of these tactics have proven effective for managing affective disorders such as depression. In this case, however, subjective mood is more readily available for monitoring, as there is no need for a special device such as a glucometer or blood pressure cuff. The diabetic and hypertensive also have the challenge of learning to discount their affective states, which are likely inadequate indicators of their underlying physiology.

Chronic Illnesses That Are Experienced as Episodic: Asthma Self-regulation of asthma provides insights into two other features of the self-regulation process, both of which are age related with one more strongly so. Having asthma is seen as occurring out of time for older persons lacking an asthma history, as asthma is widely perceived as an illness of children and adolescents. Late-onset asthma, however, is a reality and is possibly different in its pathophysiology from early-onset disease. More important for self-management is the episodic nature of asthma flares; unless the person is a careful self-observer, the life experience of both the old and young asthmatic is one of normal, symptom-free periods punctuated by attacks. Not surprisingly, many asthmatics, even those hospitalized with severe attacks, behave as if no symptoms means no asthma. In a study of hospitalized patients, middle aged and elderly, they were using both of their medications, preventers that are to be used when asymptomatic and controllers to be used during an attack, only when they were having attacks. The schema or pattern underlying their behavior fits the model of no symptoms, no asthma. They also verbalized what might seem contradictory beliefs: they believed that they would have asthma for the rest of their lives (80% of the 200 patients), but they also believed that they had it only when they had symptoms (53% of the patients), a chronic, episodic disease, and that was treated as such. The underlying schema of the self with disease was the framework of inadequate self-management.

Health Behavior in the Absence of Disease

Multiple case histories can be found of the adoption of health behavior in the absence of diagnosed disease and, presumably, the absence of disease symptoms. An article in the Science section of the *New York Times* described the daily exercise routine of Bernyce Edward, a 73-year-old exercise zealot who begins her daily hour-long routine of walking and running at 5 a.m. The trigger for this late life regimen was the death from breast cancer of her 42-year-old daughter, a fatality that occurred 69 days after diagnosis. In this article, Kolata cited epidemiological and physiological research that provides support, albeit tenuous, for the elder Ms. Edward's beliefs and health behavior. Although the all-too-obvious trigger, her daughter's death, is hardly a claim for the scientific power of self-regulation models, its presence is consistent with the model's assumption that concrete, experiential factors, symptoms, and serious consequences observed in self and others are triggers for health action. We do not know what sustains Ms. Edward's exercise zealotry, but a self-regulation model would make

the following prediction: the sense of safety is likely critical, but more importantly, this sense is based upon concrete feelings of vigor generated by exercise and by the reassurance generated by the absence of symptoms and signs of disease.

The Feel-Good Heuristic If feeling good serves as an indicator of health, we can imagine that healthy behaviors that stimulate these feelings will be adopted to promote health. Exercise is clearly such a behavior; exercise can elevate feelings of wellness and help to overcome severe depression, though it seems to be more effective in this regard for men than for women. However, good feelings can reinforce unhealthy behaviors, and healthy behaviors may elicit negative feelings. Exercise is a source of aches and pains that are likely to discourage the behavior, particularly among the elderly. And the comfort of the couch and comfort foods can be positive for the sedentary, both young and old, and dangerous for health in both. Whether the comfort of inactivity and the mild aches and pains of activity are seen, respectively, as healthful and harmful or as harmful and healthful depends upon how these cues are interpreted. Good feelings may usually seem a positive, healthy sign, but the meaning of each is also dependent upon the image of the experiencing self, the network of meanings linked to beliefs about who one is and the sense of self as a viable, energetic being. Persons who see themselves as vigorous and active are less likely to associate positive health with feeling good from hours on the couch or negative health with the aches and sweat following exercise. The meaning created by these somatic sensations is created by their embedding in a self-schema. This reflects an accumulated history of images of the self as alive and vigorous following intense, sweaty exercise, rather than feeling profoundly exhausted and lacking physical resources (**Figure 1**, arrows a1 and a2). Self-regulatory strategies such as conservation and use it or lose it linked to these self-schemata will affect the choice of response to the perception of a health risk (**Figure 1**, arrow a3). Belief in conservation among elderly individuals deters taking on new activities to substitute for more vigorous behaviors (walking instead of jogging) that were given up following serious illness. Although the strategy of conservation is somewhat more common among the elderly and that of use it or lose it is more common among the young, the age differences in these strategies may be less pronounced than one might expect. It also seems reasonable to expect that exercise-induced muscle fatigue or pain is more likely to be interpreted positively, as a sign of a good workout, in the young and as a possible indicator of harm in the elderly, especially among elderly with symptomatic osteoarthritis; the younger are monitoring benefit while the elderly are monitoring injury.

By connecting the self-regulation process to the maintenance of self-identity we can see that the same self-regulatory system underlies health behaviors during illness as well as in anticipation of, and in the absence of, a health threat. The role of symptom experience in triggering health actions may be taken over by assessments of the self as being in poor or fair health rather than excellent health, with negative appraisals of health increasing the elderly person's willingness to adopt active, health-promoting behaviors such as reducing fat intake. But self-assessment of health is an abstraction and is likely to be less potent in motivating healthy actions than the experience of increasing frailty or its opposite, the experience of well-being in response to specific physical demands. Unfortunately, feeling good is not a reliable cue to health benefit.

Action Plans Discussion of action plans for self-regulation has been deferred to this section on management of behaviors in the absence of illness or illness threats not because plans are unimportant during illness, but because the plans seem more salient for action in the healthy state. Although plans do not seem sufficient to motivate behavior, they are critical for its implementation. Plans have an exceptionally powerful effect on translating motivation into performance, and they seem to do so for the following reasons. First, they automate behavior. A good plan will identify specific cues, times, and places for initiating action. As the action is often the first in a sequence, its occurrence both cues and motivates subsequent behaviors; e.g., heading to the gym or exercise bicycle is likely to follow the automatic search and donning of gym clothes and sneakers at the usual time of day. Second, whether it is exercise, shopping for fruits and vegetables, or cooking a low-fat dinner, plans integrate the behaviors into the ongoing daily framework of activities. Defining the framework, isolating the place for the behavior, selecting the time frame for action, and developing (thinking of) expectations for outcomes are part of routinizing the behavior; making it part of necessary life conditions. Given the diversity and range of events from subjective feelings, through observations of the behavior of others to media exposures, it is much more difficult to identify a specific basis for motivating health-relevant actions. We suspect, however, that subjective feelings of the presence or absence of well-being play an important role.

Conclusion: Is There a Good Match between the Self-Regulation System and the Biological Progression of Disease Risk?

Our focus has been on the factors involved in the self-regulation process and the variation in the salience of different factors as a function of context. The context of major concern was the presence or absence of diagnosed or suspected disease, and the presence or absence of symptoms or functional indicators of disease. Symptoms and function play a major role in the individual's initiation and evaluation of behaviors, often more so than objective disease indicators. Indeed, the match and/or mismatch of experiential factors guiding behavior and the objective impact of behavior are central to understanding how self-management can produce benefit or harm over the long term. Behavioral management is increasingly complex for asymptomatic chronic illnesses as well as chronic episodic conditions. The lack of experienced benefit for behavioral self-management in hypertension and diabetes makes it difficult to sustain motivation and behavior for control over the longer term. To date, behavioral techniques for shifting control from subjective to objective indicators have proven of modest benefit, as have techniques for motivating behaviors for promoting health in individuals who are disease-free and asymptomatic. The match and mismatch of subjective feelings to objective status, e.g., smoking cigarettes feeling stress reducing and relaxing to practiced smokers, presents both opportunities and barriers to programs of healthy action. Plans that facilitate the automation and integration of behavior into the daily routine play a critical role in all contexts.

Finally, placing the topic of health behaviors within a self-regulation context has led to the emphasis on individual factors, the representations of illness threats, heuristics for appraisal, plans for implementation, and self-appraisals of health. The social context was touched upon as a trigger motivating health behaviors, but a fuller treatment of the interactions among social and individual-level factors within the self-regulation framework requires separate treatment.

See also: Cardiovascular System; Decision Making and Everyday Problem Solving; Diabetes; Diet and Nutrition; Exercise and Physical Activity.

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Sexuality, Sensuality, and Intimacy

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Glossary

Culture – Global social influences that moderate the expression of hard-wired dispositions.

Inclusive Fitness – The survival to reproductive age of succeeding generations of offspring.

Love – Includes passion, intimacy, and commitment.

Successful Aging – A concept to describe how personal control, life style, and social support may enable older people to retain vigor and activity even with disability or disease.

Introduction

This article examines sexuality, sensuality, and intimacy in later life. This topic received considerable public attention during the past decade because of advances in the treatment of erectile dysfunction in men. The present era of openness contrasts with centuries of sexual ageism that was supported by religious beliefs in Western countries. Although aging has effects on sexual functioning, the main influences on sexuality in later life include opportunities and attitudes, health and disability, and the use of effective treatment for sexual problems. The article also includes discussion of sexual preferences and satisfaction in older people and issues about sexuality in institutions.

Perspectives on Sexuality and Intimacy

One of the great debates of past and present times concerns the effects of nature and nurture on human behavior and feelings. With regard to sexuality, it may seem surprising that those whose beliefs descend directly from Darwin's theory of evolution – the nature group – are bedfellows with those whose beliefs devolve from the traditions of Western religion. Both types of belief inform us that sexuality is hard-wired into our bodies for the purpose of procreation; once the age for procreation has passed, sexuality that fails to fade to inconsequence may be deviant. To other scientists and humanitarians – the nurture group – sexuality has as much to do with love as with procreation. A concept about love that continues to influence psychologists includes three main qualities of passion, intimacy, and commitment. Early love is usually passionate, lasting love is committed, and intimacy fosters caring. From this perspective, sexuality can promote bonding and commitment in partners of any age to provide care for each other and succeeding generations.

Modern interpretations of evolutionary theory (i.e., termed neo-Darwinian) include beliefs consistent with those of the nurture group. Although Darwin thought that the currency of evolution was reproductive success, neo-Darwinians refer to inclusive fitness as the survival to reproductive age of succeeding generations of offspring. Consequently, genes to extend the human life span beyond the age of reproduction probably proliferated in our species because the prolonged immaturity of offspring necessitates an enduring period of nurturing to ensure their survival. If sexuality provides a glue to help maintain the commitment of parents (and grandparents) within a familial context, it would be surprising if genes to prolong sexuality beyond the reproductive span did not proliferate accordingly.

A premise widely accepted within science is that sexual behavior, like other behaviors, reflects an interaction between nature and nurture. The term culture is used to describe global social influences that moderate the expression of hard-wired dispositions. Major cultural changes in Western countries in the 1960s coincided with a wider acceptance of contraception, the advent of efficient birth control that provided women with the means to regulate their reproduction, accumulated successes of the suffrage/feminist movements, and the transition to adulthood of the first wave of the post-World War II Baby Boomers. Following the sexual revolution of that era were changes in behavior and social customs that include an earlier age for first intercourse, lower fertility, more frequent divorce, a declining rate of heterosexual marriage, and the acceptance of gay and lesbian marriage in some countries (e.g., Canada). The older Baby Boomers who participated in that revolution are now near the cusp of later life. We can be sure that their transition into old age will bring significant new changes to the culture surrounding later life sexuality.

A symbolic dividing line that brought later life sexuality into public consciousness was the appearance of the drug sildenafil (Viagra) in 1998. This drug was the first effective oral medication to assist men with erection; however, its impact on social beliefs and attitudes extended well beyond the therapeutic paradigm. Viagra emerged toward the end of

an era of widespread re-evaluation of beliefs and attitudes about aging. The life and social sciences had accepted that earlier research findings were overly pessimistic about the effects of aging on functional capabilities. Successful aging had become a widely used concept to describe how personal control, lifestyle, and social support enabled older people to retain vigor and activity even with disability or disease. This concept provided an impetus for scientists to correct the fallacious beliefs that later life was a period of pervasive decline with limited opportunities for personal growth and development. Trends toward a more optimistic outlook on aging were also apparent in the arts, humanities, and governmental policies of many Western countries. Such changes provided the context for a reappraisal of sexuality in later life.

Academic and popular publications from the pre-Viagra era concluded that ageism had dominated considerations of later life sexuality in Western countries for centuries. Scientists reached a similar conclusion that ageism had hindered the progress of scientific research on later-life sexuality. Clinicians railed against the harmful effects of sexual ageism to advance a self-fulfilling prophesy – people may inhibit their sexuality because they expect it to decline – and provided abundant evidence that sexual interest persists into old age. However, it took the release of Viagra to bring these appraisals to full public awareness.

The publicity unleashed by Viagra transformed the cultural standing of later-life sexuality from a nearly taboo topic to the forefront of public consciousness as a normal, acceptable, and desirable form of behavior. We should have no doubts that the early years of the twenty-first century will continue to reflect the influences of this drug on the attitudes, sexual behavior, and social customs of an aging population. However, the cumulative effects of this cultural transition are likely to be gradual rather than abrupt. During any period of cultural change, an elderly cohort may be more prone to retain the attitudes and behaviors of an earlier time than upcoming elderly cohorts. Evidence for such disparity already exists: a belief that sexual intercourse outside marriage is wrong (in later life) is more frequent within cohorts already old at the turn of the millennium. This belief limits the opportunities for sexual activity during widowhood and has origins in sexually ageist religious philosophy. Because it is impossible to understand or anticipate changes in sexual attitudes, beliefs, desires, cognitions, and behaviors outside of the cultural context that informs them, this article includes a review of sexual ageism from historical and cross-cultural perspectives.

Ageism and Sexuality

The Scope of Sexual Ageism

Ageism refers to stereotypical attitudes toward older people. Many authors have noted that nowhere is ageism more apparent than in attitudes toward sexuality. Depictions of elderly people in the folklore of Western countries show both positive and negative stereotypes. The positive stereotypes depict Grandma bustling around the kitchen baking cookies for succeeding generations of offspring while Grandpa reminisces about good old times with his cronies. Neither of these mythical folk figures needs ongoing sexuality to sustain commitment and intimacy, with sexual passion having run its course long before. The stereotypes are less benign for old people who retain sexual interest and involvement. Behaviors considered lusty or virile in a young man become described as lecherous if shown by an older male, who according to traditional beliefs is supposed to have become asexual. Sexually provocative or seductive behavior in an old woman is evidence in folk culture for emotional disorder, depravity, or a grim and sorry attempt to retain hold on a long-lost youth.

Art, history, and science show similar stereotyping. Most Western literature until recent times showed indifference or pathos toward sexuality in later life. When sexual inclination was portrayed, the main image of the older man was of a pathetic creature and the older woman as depraved. Chaucer's *Merchant's Tale* relates the sorry story of a boastful old knight called January. January married a younger wife who cuckolds him, with her infidelity due to January's impotence. The inability of the lecherous "old fool" to attract and keep faithful a beautiful young woman is common to literature and painting in the medieval era. Many paintings were variants of Lucas Van Leyden's *The Fool and the Young Women* (1520) or Massey's (1446–1530) *Ill-Matched Pair*. The latter shows an old man trying to seduce a young woman with the help of his moneybag. The theme is that an old man's sexual aspirations are well beyond his capabilities.

The most violent period in history that accompanied an alleged association between depravity and sexuality in older women occurred during the witch-hunting era in Europe, which continued throughout the fifteenth to seventeenth centuries. The official manual on witch hunting was the *Malleus Maleficarum* (*Hammer of Witches*, 1486). The premises of this manual include beliefs that witchcraft originates from carnal lust and that deviant sexuality provides evidence for witchcraft. Records indicate that an overwhelming majority of witches (e.g., approximately 90%) were women, mostly aged in their 50s or 60s, with many occupied as midwives.

In science, the pioneering studies of human sexuality in the mid-twentieth century were largely indifferent to later-life sexuality. Kinsey and his colleagues collected less than 1% of their data from people aged over 60 years, and they devoted only 7 pages out of 1646 in their books on male and female sexual behavior to sexuality in later life. Masters and Johnson studied few older people in their seminal research. It is probable that the same sexual ageism that informed popular opinion influenced these pioneering scientists.

The Relevance of Religious Philosophies

Most writers on sexuality blame the early Christian church for propagating the idea that sex is sinful outside the contexts of marriage and procreation. Such commentators consider the originator of Western religious teaching to be St. Augustine (354–430), whose ideas resonated with those of influential medieval theologians like Albertus Magnus (1206–80) and St. Thomas Aquinas (1225–74). Although St. Augustine's doctrines came under attack from the Protestant reformers in later centuries, aspects of his teaching continue to endure in our culture. Of particular significance to the present discussion, the teaching that sex for purposes other than procreation (e.g., enjoyment, comfort) is wrong connotes an attitude that later-life sexuality is likely to be sinful.

St. Augustine's most influential book was *De Civitate Dei* (*City of God*), which he completed after 14 years of writing at the age of 72 years. This book portrays the Garden of Eden as a place without lust, passion, or pain. This serene existence, St. Augustine wrote, would have been possible for everyone had Adam and Eve not sinned, with the whole procreation process from conception to childbirth meant to be harmonious and contemplative. Lust, passion, and pain had no place in St. Augustine's Eden, being both sinful and consequences of sin. The notion that sex is sinful but tolerable only for purposes of procreation is central to St. Augustine's philosophy.

There can be little doubt that the notions about sexuality proposed by St. Augustine and his successors would have been contested vigorously had they been propagated during an era when clerics exerted less authority over the populace. However, conditions of diminished literacy and learning in the classical world resulted in few challenges to these teachings, which eventually became accepted as lore and dogma. Although the Roman Catholic Church remains somewhat faithful to St. Augustine's ideas, such sixteenth-century reformers as Calvin and Martin Luther saw little wrong in sex that was confined to the marriage bed. Jeremy Taylor commented in the nineteenth century that the reformers welcomed sex as a means to produce legitimate children, avoid fornication, provide solace, and promote bonding of husband and wife. Although the reformers' prescription does not disparage later-life sexuality as deviant, outside of the marital mode St. Augustine's veto prevailed.

The belief that sex is sinful finds no place in other major religious philosophies (e.g., Taoism, Confucianism, Hinduism, Buddhism, and Islam). These religions embrace rather than reject sexuality, and some consider sexuality a means to enlightenment. The *Li-Chi* (*Book of Rites*) even contained prescriptions for the sexual welfare of the older woman: for an aging concubine of less than 50 years, the *Li-Chi* recommends that her husband have intercourse with her once every 5 days.

The traditions established by the early Christian church provide more support for sexual ageism than those of other religions, with this legacy continuing to endure in Western culture. However, it seems likely that adherence to those traditions will diminish in the coming decades.

Age Trends in Sexuality

Physical Age Changes

The full range of sexual behaviors includes preparatory behaviors (e.g., cuddling, hugging, kissing, petting) that may lead to intercourse and subsequent orgasm. Humans respond positively to benevolent tactile stimulation from the cradle to the grave, with no evidence to suggest that the capacity to enjoy sensual experience is lost with age. Although age changes in physiological functions have effects on sexual capability, neither intercourse nor orgasm is difficult to achieve for the majority of older people. **Table 1** shows some frequent physiological age changes that pertain to sexual performance and advice on dealing with such changes. The main age changes for men and women include delayed arousal, less intense orgasm, and a more rapid return to quiescence. The man may need extra stimulation to achieve erection and a longer recovery period between repeated intercourses. The woman may require external lubrication, more stimulation of the clitoris, and regular sexual activity to continue to enjoy sexual intercourse without discomfort. Despite a loss of sexual vigor compared with younger times, many authors point to the perils of a fallacious self-fulfilling prophesy that intercourse becomes all but impossible in later life.

Table 1 Age changes affecting male and female sexuality and ways to deal with such changes

Changes in men	*Changes in women*
The man is aroused less easily	Vaginal lubrication is both slower and diminished
Erection takes longer	The vaginal walls thin and become irritated more easily
The erection may not be as hard	The vagina may change shape to become shorter and narrower with less expansion
The ejaculation takes longer, with slower urethral contractions that may feel less intense	The clitoris becomes more exposed to irritation and may decrease in size very late in life
Return to a pre-arousal state after ejaculation takes a shorter time	The bladder and urethra (through which urine passes) become more susceptible to irritation and bacterial infection
It takes longer after ejaculation before the penis can come erect again	Vaginal contractions in orgasm are less frequent and may be painful
Practical advice about physiological changes	The older woman should take extra care to maintain cleanliness, use lubricants, and keep sexually active. Even a short abstinence may cause older women to experience temporary discomfort when resuming sex
A positive effect of these changes is that an older man is more in control of his sexuality than when younger. He can prolong the duration of intercourse more easily. The negative effects are that the man may need extra stimulation for arousal and intercourse may be less frequent	

Table 2 Percentages of male and female respondents in three cohorts with at least weekly occurrences on measures of sexuality; percentage of respondents with an available sexual partner

Measure	*Males*			*Females*		
	Youngest	*Middle*	*Oldest*	*Youngest*	*Middle*	*Oldest*
Sexual thoughts	83%	53%	36%	42%	14%	4%
Sexual desires	86%	54%	37%	41%	21%	8%
Kissing or hugging	77%	73%	63%	72%	49%	28%
Sexual touching or caressing	69%	61%	45%	61%	37%	15%
Sexual intercourse	55%	31%	19%	50%	24%	7%
Oral sex	20%	6%	9%	19%	2%	1%
Self stimulation	33%	14%	5%	4%	2%	1%
Sexual partner available	84%	79%	58%	78%	53%	21%

Sexual Desires, Cognitions, and Behaviors

Studies of later-life sexuality became a frequent focus of research only during the 1980s. Several surveys refuted earlier beliefs that sexual dysfunction and a loss of sexual interest inevitably accompany aging. Limitations to these studies included inadequate sampling and measures of sexual behavior confined to the self-reported frequency of intercourse. Several studies in the 1990s and later were methodologically stronger, with representative sampling and measures of multiple modes of sexual behavior and cognition. Good examples include extensive surveys by the American Association of Retired Persons/*Modern Maturity* Sexuality Study in 1999 and 2004. The earlier study (termed the AARP study in this article) included 639 males and 745 females randomly sampled from a panel of people aged 45 years and older that was broadly representative of American households. The response rate for panelists providing data was 76% of those who satisfied a set of inclusion criteria. The analysis of age effects compared cohorts termed here as the youngest (45–59 years), middle (60–74 years), and oldest cohorts (75+ years). Because the AARP study provides what may be the most accurate portrayal of later-life sexuality in modern America, subsequent discussion uses findings from that study to illustrate age trends.

The measures indicative of sexual interest and activity in the AARP study included sexual thoughts and desires and multiple measures of sexual behavior. **Table 2** shows the percentages of respondents with at least weekly occurrences of these measures. With respect to sexual thoughts and desires, the upper two rows of **Table 2** show two main trends. First, the levels are higher for males than females at all ages. This trend is consistent with other findings that sexual cognitions tend to be higher in men than women regardless of age. Second, the frequencies of sexual thoughts decrease with age in both gender groups.

The sexual behaviors surveyed in the AARP study included kissing and hugging, sexual touching and caressing, sexual intercourse, oral sex, and masturbation. With the exception of self-stimulation, which

was rare in women of any age, inspection of rows 3–7 in **Table 2** shows that the frequencies of men and women with at least weekly occurrences of the other sexual behaviors were nearly identical in the youngest cohort. The most frequent behaviors were kissing and hugging, followed by sexual touching or caressing, sexual intercourse, and oral sex. The frequencies of each of these behaviors decreased with age, with the decreases generally higher in women than in men. Several other findings show comparable age declines in the frequency of sexual intercourse. Although most studies compared cohorts of different ages, longitudinal research shows a similar trend: over the course of a decade, the decreases in sexual intercourse per month were three times higher for men in their 60s than for men in their 40s.

The potential for orgasm during intercourse may decline with age but remains within the realm of experience for the majority of older people. Over 75% of men of any age in the AARP study reported that they always or usually experienced orgasm during sexual activity. The proportion of women reporting orgasms was lower, with 46% of women from the oldest cohort reporting that they rarely or never had orgasms.

These findings on age trend suggest that middle-aged men desire sex, think about sex, and masturbate more frequently than women of similar age. Middle-aged men are also more likely to report orgasm than middle-aged women. All other forms of sexual behavior (kissing and hugging, sexual touching and caressing, sexual intercourse, oral sex) are of comparable frequency between the gender groups. Declines with age occur on all measures of sexuality, with the losses greater for women than for men on most measures. However, these declines are a function of multiple factors, not merely age alone.

Influences on Sexual Age Trends

Opportunities and Attitudes

The reasons for declining rates of sexual activity with age in men and (particularly) women include opportunity and attitudes. The opportunity to engage in sexual behavior depends on the availability of a partner. Most publications on sexuality in later life cite the lack of an available partner as the main reason for lower levels of sexual activity in older women than in older men. The origins of this discrepancy are demographic: spousal age differences, gender differences in life expectancy, and gender differences in rates of remarriage after widowhood all contribute to a surplus of elderly widows over widowers.

The bottom row of **Table 2** shows the proportions of men and women in the AARP study with a sexual partner. The frequencies in the youngest cohort are similar between men and women at 84 and 78%, respectively. However, many more men (58%) than women (21%) in the oldest cohort had a sexual partner. These percentages approximate the marital rates for men and women in the different cohorts, suggesting that sex outside of marriage was infrequent in the sample. Other findings showed that men and women with a partner had nearly identical frequencies on all measures of sexual behavior except for masturbation. The frequencies were lower in men without partners than with partners and at near-zero levels on most measures for women without partners. These findings support the supposition that the lack of a sexual partner contributes to age decline in sexual activities.

Negative attitudes toward sex outside marriage can restrict opportunities for sexual involvement by unmarried people. The AARP study showed that more women than men thought that sex outside marriage was wrong, with adherence to this attitude higher in the older cohorts. In the oldest cohort, half of the men and two-thirds of the women thought sex outside marriage was wrong.

Health and Disability

Numerous diseases, disabilities, surgeries, medications, and sources of pain or discomfort affect sexual behavior either directly or through a lowering of libido. Consequently, it is unsurprising that the AARP study showed the highest frequencies for sexual cognitions, desires, and behaviors in people reporting that they were disease-free and taking no medications. Although the direct effects of many illnesses on sexuality are acute rather than chronic and diminish after successful treatment of the precipitating condition, psychological reactions to illness or during the recovery period may prolong the period of disorder. Recent publications refer to the effects on sexuality of depression, adverse psychological reaction following a stroke or heart attack, and the treatment of breast cancer. During periods of treatment or recovery, intervention may be necessary to counter myths that sexual exertion may be harmful, sexual performance compromised, or interest in sexuality and intimacy diminished following a successfully treated illness.

Medications (e.g., beta-blockers, tricyclic antidepressants, corticosteroids, and major tranquilizers), recreational drugs (e.g., alcohol), and pain and discomfort (e.g., arthritis, back pain) may inhibit sexuality. Many publications discuss ways to alleviate these problems.

Chronic neurological conditions such as dementia may affect sexuality and the capacity for intimacy. Research on sexuality in people with dementia suggests that half or more of patients show negative sexual behavior changes during the illness, although their frequency of intercourse may remain at rates comparable to those of age peers until the final stages of the disease. Some people with dementia show a decrease in sexual manners, with less consideration for their partner than formerly. Some have an increased interest in sex or become sexually overdemanding, aggressive, or inappropriate. Others display a decreased interest in sex although they are likely to retain a need for physical contact (e.g., hugging, kissing, and cuddling). Throughout the course of the illness, the nature of sexual intimacy between the patient and partner requires continual redefinition, with help from support groups or professional assistance sought if necessary.

Although many spouses of dementia patients experience the caring process as a time of burden and regret the loss of intimacy brought about by the effects of the disease on cognition and personality, other caregivers react differently. These caregivers report increased intimacy with the patient, particularly during the earlier stages of the illness. The enhancement in intimacy appears to result from their devotion to the patient during that time.

Other research examined the positive effect of sexuality on the prevention of subsequent illness. Whether a person is healthy or handicapped at baseline assessment, sexually active people may experience lower frequencies of subsequent incidents compared with less-active age peers.

Treatments for Sexual Dysfunction

The main sources of sexual dysfunction in older men include erectile difficulties and low libido. A problem reported in the clinical literature is that the shame that sometimes accompanies erectile failure can inhibit sexual interest and cause a cessation of sexual behavior. Many clinicians noted that if a couple ceases to be sexually active, treatable erectile failure is among the most common causes. Findings on reported impotence in the AARP study showed that the proportion of men reporting complete impotence increased from 2% in the youngest cohort to 38% in the oldest cohort. Recognized categories of sexual problems in women include hypoactive sexual desire, sexual arousal disorder, orgasmic disorder, and sexual pain. Although some authors warn against the use of medical taxonomy to describe individual differences in female sexuality, relatively few older people of either gender seek advice or obtain treatment for sexual difficulties.

Findings from the 1999 AARP study showed that only 13% of men and 6% of women sought treatment for sexual dysfunction from their personal physician. Those who received treatment from any source comprised 10% of men and 7% of women, with the most frequent treatments being Viagra and Premarin, respectively. At the time of the 2004 AARP survey, the number of men and women that sought information about sexuality or received treatment for a sexual functioning problem increased significantly.

Earlier treatments for erectile problems in men included alprostadil injection and penile implant surgery. After 1998, the use of these treatments diminished considerably in favor of Viagra and other phosphodiesterase inhibitors (e.g., tadalafil, varenafil) that assist erection. Viagra showed an 84% increase in the number of commercially insured users in the United States within 4 years of its introduction, with the growth in use increasing particularly in males aged 45 years or younger. Research on the effectiveness of Viagra shows an improvement in erectile function compared with placebo. Studies of therapeutic success show that half or more of the older men with erectile difficulties report gains in sexual performance after a course of treatment.

In addition to improved sexual performance, treatment by Viagra may improve the quality of relationships with a sexual partner. In multiple studies, the satisfaction with intercourse was higher in the partners of men using Viagra than in partners of men using a placebo. The partners of men using Viagra report other positive changes that included increases in feelings of closeness and togetherness and a decrease in the frequency of quarrels. However, a proportion of successfully treated men discontinue usage of Viagra. The main reasons for discontinuation include the lack of a partner and emotional disinclination to resume a sexual relationship either by the man or by his partner.

Although phosphodiesterase inhibitors like Viagra assist the erection process, they may be ineffective in the presence of low testosterone (i.e., hypogonadism), which contributes to low libido, failure of erection, depressed mood, fatigue, osteoporosis, and loss of lean body mass. Men with low testosterone, including those who failed to respond to sildenafil therapy alone, may respond well to testosterone replacement therapy.

Emotional readiness for intimacy is a necessary precondition for a satisfying sexual relationship. Sexual therapists use counseling to help older men and women correct relationship problems and

alleviate sexual difficulties. One aspect of counseling concerns sources of sexual arousal, which are more visual and tactile in men but emotional in women. Another concerns the achievement of sexual satisfaction in cases in which penetration is improbable. Shortcomings in the treatment of sexual disorder by family physicians include an overreliance on physical treatments without the requisite counseling to provide an inclusive therapeutic context.

Sexual Preferences and Satisfaction

Sexual Preferences

Heterosexual men typically have sexual partners of a similar age or younger, whereas women have sexual partners of a similar age or older. An evolutionary perspective on mate selection suggests that such preferences reflect gender differences in reproductive strategy. Men may select women for their youth and attractiveness; women may select men for their potential to supply resources. Partner preferences in later life also reflect needs for companionship.

Qualitative studies on the reasons for dating found that older people cite companionship as a main reason. Quantitative analysis of advertisements placed in the personal columns of community newspapers shows that men and women of all ages differ in the preferred age for partners in directions predicted by evolutionary theory. However, the same advertisements showed that people from older cohorts mainly cited friendship as the desired quality in a relationship, with older women particularly disinclined to mention longer-term commitment.

Older gay, lesbian, bisexual, and transgender individuals remain a largely invisible population with respect to research on geriatric sexuality. Although such individuals comprise a minority among the population, the proportion among the older cohorts willing to participate in research on sexuality may be lower than at younger ages. Although the recent medical literature includes several studies with an emphasis on risk factors for sexually transmitted diseases, much of the other research focuses on the health, social service, and community needs of older gay and lesbian people.

Sexual Satisfaction

Even though reported satisfaction decreased with cohort age, more respondents in the AARP study reported satisfaction than dissatisfaction with their sex lives. The presence of a sexual partner, not surprisingly, resulted in higher levels of satisfaction. More women than men were satisfied with their sex lives (and fewer women were dissatisfied) regardless of the presence or absence of a partner, with a similar gender difference found in other research. These findings are consistent with other studies showing that sexual satisfaction is normal in older cohorts. The strongest predictors of sexual satisfaction at any age include the sexual satisfaction of the respondent's partner.

Sexuality in Institutions

Long-term care brings special challenges because a significant proportion of residents have some form of dementia. For people without dementia, privacy should be primary to their ability to enjoy sexual relations. Although many institutions provide privacy rooms to facilitate sexual enjoyment by residents, the attitudes of other people may provide barriers to pleasurable sexual expression. First, the families of sexually active residents of a long-term care home may be unsupportive or hostile toward those residents and berate staff for allowing such behavior. Second, sexual activity by some residents may evoke feelings of disapproval or jealousy in other residents and contribute to conflict and disharmony within the home. Third, sexually ageist attitudes by staff may result in neglect or ostracism of sexually active residents. Some commentators consider such reactions by staff as a form of emotional abuse.

Sexual behavior in dementia brings special ethical challenges in addition to social and professional concerns. For people with dementia, questions of their desire and competency take precedence. Although there is no good reason to prevent people with dementia from enjoying a sexual relationship, it is important to respect their desires and ensure an absence of coercion or unwanted persuasion. Examples of unwanted sexual activity include sexual advances by another resident or by the spouse of a resident living outside the home. There have been cases where criminal prosecution for sexual assault was possible against spouses who demanded the right to a conjugal relationship that threatened the well-being of demented residents.

Staff members bring to a long-term care home their own attitudes and beliefs about unseemly sexual behavior. Sexual display by residents may offend some staff members, especially if they consider such behavior to be socially inappropriate. Staff members assign some level of personal responsibility even to demented residents and may mistakenly attribute inappropriate sexual expression to the character of the resident rather than poor judgment caused by illness.

Staff members also perceive their own responsibility not to expose themselves to sexual advances by residents, and these feelings may affect their behavior toward some residents. Because many staff in long-term care homes receive only rudimentary training about residents' sexuality as part of their educational programs, the need for ongoing in-service training is essential.

Conclusions

The evidence is unequivocal that, contrary to Western traditions of sexual ageism, sexual interest and behavior persist though middle age and into later life. Although physiological changes have qualitative effects on sexuality, quantitative declines with age are associated with limited opportunity, illness and disability, and failure to procure treatment for problems. Findings on attitudes show the significance of sexuality in the lives of middle-aged and older people. Most of those with a partner believe that sexual activity is critical to the quality of their relationship; those without a partner assign less importance to intimacy and report a lower quality of life.

Because sexual activity is so important to intimate bonding, findings that relatively few older people sought help for sexual difficulties as recently as 1999 may seem surprising. There are several reasons for such disinclination. First, sexual ageism contributes to a self-fulfilling prophesy that sexual limitation is normal in old age. Second, effective oral medication to treat sexual dysfunction is of recent origin and targeted only toward men. Third, the opportunity and quality of relationship are limiting factors for sexual enjoyment, particularly in women. Finally, the effects of disuse appear to apply as much to sexuality as to other spheres of activity: sexual disengagement contributes to disinterest.

Cultural changes of relevance to later-life sexuality are both apparent and impending. Such changes concern treatment of problems and opportunities for sexual participation. First, sexual ageism weakened after the introduction of Viagra, with sexuality in later life reappraised as normal and desirable. A consequence concerns the treatment of sexual dysfunction in upcoming cohorts of the elderly. Because of the use of Viagra as an aphrodisiac within younger cohorts of men and women, future cohorts of the elderly may have fewer inhibitions about procuring help for sexual problems. Second, awareness and sensitivity about the effects of illness and disability on sexual behavior are increasing within medicine. These changes should provide a supportive context to facilitate treatment. Third, opinions that sex outside marriage is wrong are weaker within younger cohorts. These cohorts are also more accepting of alternative sexual preferences and lifestyles. Likely consequences are that widowhood and status as a single person may be less formidable barriers to sexual opportunity in the future.

Anticipated effects of these cultural changes include a gradual turnaround of the ageist convention that sexuality normally dissipates in later life. The perspective that replaces it will likely consider sexuality that endures until very late in life to be a normal human option, sexual dysfunction a condition often amenable to treatment, and sexual disinterest an unfortunate but not necessarily deviant state of mind.

See also: Erectile Dysfunction; Long Term Care.

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Skill Acquisition

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Glossary

Associative Learning – The process of strengthening the associative link between a stimulus and a response that underlies automatic processing.

Consistent Practice – A type of practice in which the stimulus–response associations are consistently maintained throughout training.

Part-Task Training – A training procedure in which the consistent components of a task are practiced separately from the complete task.

Priority Learning – The process of modifying the attention-capturing properties of a stimulus leading to the automatic capture of attention.

Proactive Interference – A situation in which prior learning interferes with learning new material.

Variable Priority Training – A training procedure in which subjects are trained to flexibly share attention between two tasks performed concurrently.

Introduction

One of the most important properties of human behavior is the ability to acquire skills that allow people to perform complex operations quickly and accurately with little thought or effort. For example, consider the task of driving an automobile. New drivers often find driving quite demanding, and the rate of traffic accidents is remarkably high for these individuals. Analysis of fatal accidents indicates that it takes several years for drivers to become proficient. Once they have mastered this skill, people are often able to perform several multitasking operations while driving without running off the road (although in many instances these multitasking activities do increase the overall risk of accidents). Indeed, skilled performance is often characterized as fast, effortless, and relatively free of capacity limitations. Given the importance of skill in everyday behavior, a critical issue is how normal aging influences the ability to learn new skills. Is there any merit to the old adage that 'you can't teach an old dog new tricks'?

In contemporary society, new technologies often obligate people to learn new skills. For example, the introduction of the computer into the workplace in the mid-1980s necessitated the acquisition of a new class of skills for a large segment of society. Computers in one form or another now play a central role in almost every aspect of daily life. Using the Internet has become a critical skill, needed for online banking, making travel plans, communicating via e-mail, etc., and there are often penalties for not using this new technology (e.g., some airlines charge a fee when tickets are purchased through a customer representative rather than via the Internet). Are older adults as facile at learning the skills necessary to use these new technologies as their younger counterparts? The purpose of this article is to examine the role of normal aging in the ability to acquire new skills. The article also considers the extent to which skills acquired early in life are maintained across the age range and several strategies that may be helpful in reducing age-related differences in skill acquisition.

Skill Acquisition

Skill is thought to involve the coordination and integration of a number of component automatic processes with strategic knowledge about when and how to use these procedures. Anderson suggested that there are three phases of skill acquisition. The first phase of skill acquisition is the declarative phase. In this phase, heavy demands are placed on attention, and performance is thought to be dependent upon the general problem-solving abilities of the individual (this phase of skill is also referred to as controlled processing). The second phase is the knowledge compilation phase. Knowledge compilation involves several mechanisms for building productions that directly control behavior (e.g., composition and proceduralization) and is thought to be dependent on an individual's perceptual speed ability. The third phase is the procedural phase, which involves a gradual tuning and strengthening of productions in procedural memory, resulting in a speedup in performance, and is thought to be dependent upon psychomotor ability (this phase of skill acquisition is also referred to as automatic processing).

Ackerman developed a theoretical framework incorporating differences in general ability, perceptual speed ability, and psychomotor ability to better understand the role individual differences play in skill acquisition. Individual differences in general ability are thought to indicate differences in the efficiency of general information-processing operations and are

commonly measured with tests of general intelligence. Individual differences in perceptual speed ability are commonly measured with tasks such as the digit-symbol test and are thought to involve "the generation of very simple production systems that must be used to efficiently solve test items" (Ackerman, 1988: 290). Individual differences in psychomotor ability are reflected in measures of elementary processing speed, using, for example, simple reaction time. As the consistency of the operations within a task increases, the role that these ability differences play in skill acquisition grows. Ackerman's framework builds on the three phases of skill acquisition developed by Anderson. From this framework, differences in novice performance are largely governed by differences in general ability; differences in the rate at which individuals can acquire skill are determined by perceptual speed ability; and differences in expert performance are largely governed by differences in psychomotor ability.

The individual differences framework can also be profitably applied to the study of age-related differences in the acquisition of cognitive skill. If general, perceptual speed, or psychomotor abilities change with senescence, then it follows that there should be age-related differences in skill acquisition. Moreover, the degree to which there are age-related differences in each of these abilities will determine which phases of skill acquisition will be most affected by age. What evidence is there for age-related decline in each of these abilities? Schaie studied general ability by examining longitudinal data from more than 5000 individuals and found systematic declines in each of five primary measures of mental ability (i.e., verbal meaning, spatial orienting, inductive reasoning, number skill, word fluency), with the declines becoming most pronounced after the age of 60. In fact, the cumulative proportion of the population that exhibited declines in one or more primary mental abilities increased systematically after the age of 32. Hoyer *et al*. studied perceptual speed ability by performing a meta-analysis of 141 studies of older and younger adults on the digit-symbol subtask taken from the Wechsler Adult Intelligence Scale-Revised. The results indicated substantial declines in perceptual speed ability, with age accounting for 86% of the observed variance in test performance. Finally, Kerr and Blais observed gradual declines in psychomotor performance up to age 60, whereupon psychomotor slowing increased dramatically. Similarly, Fozard *et al*. used both cross-sectional and longitudinal analyses of 1265 adults ranging in age from 17 to 96 and found systematic increases in simple reaction time across the adult life span. Taken together, these results provide a clear indication of age-related declines in general, perceptual speed, and psychomotor abilities, suggesting that older adults should not be able to acquire skills as efficiently as younger adults and that there should be age-related differences in each phase of the skill acquisition process. Despite the fact that older adults as a group acquire skills less readily than the younger cohort, there are often cases in which some older adults perform better than some younger adults, at least on certain specific aspects of performance. However, the longitudinal studies that have been performed suggest that, relative to an individual's own baseline, his or her ability to acquire novel skills should decline as he or she grows older.

A complementary approach to examining skill acquisition and aging is to examine learning curves for younger and older adults. It is commonly believed that the acquisition of skill follows a power function, such that the improvements in performance are greater earlier in training than later in training. The generalized equation for a power function is

$$T = a + b(x)^{-c}$$

In this equation, time, T, is a monotonically decreasing function of the number of trials of practice, x, raised to the power $-c$, multiplied by the total amount of improvement, b, plus a constant, a, reflecting the lower bound of performance.

Figure 1 presents several examples of power functions that illustrate possible age–skill relationships. Note that in each of the theoretical curves in the figure, the initial level of performance is slower for older adults than for younger adults due to the ubiquitous slowing of behavior with age (i.e., general

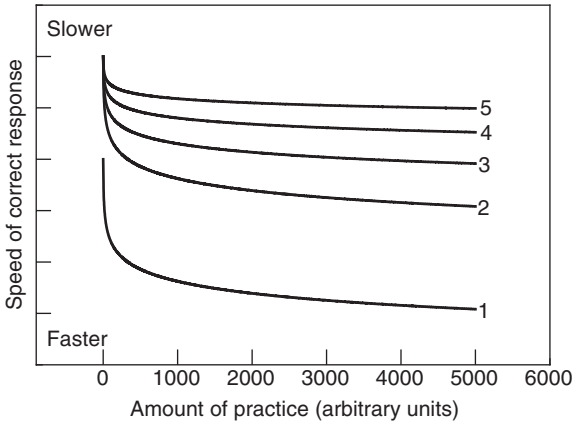

Figure 1 Theoretical power function curves illustrating four possible relationships between younger and older adults in skill acquisition. Curve 1 represents the theoretical performance of younger adults. Curves 2–5 represent the theoretical performance of older adults.

slowing). In the figure, curve 1 illustrates the theoretical performance of younger adults. Curve 2 illustrates a situation in which older adults learn the same amount and at the same rate as younger adults, but there are differences in the asymptotic level of performance (due to general slowing). That is, the *a* parameter of the power function differs with age, but neither the *b* nor the *c* parameter is age sensitive; the curves are simply displaced by the degree of generalized slowing. In such a case, a reasonable conclusion would be that there is little or no decline in the ability to acquire skills with senescence.

Curve 3 illustrates a case in which older adults learn the same amount as younger adults, but both the rate of learning and asymptotic levels of performance differ with age. In this situation, both the *a* and *c* parameters of the power function change with age, but the *b* parameter is not age sensitive. In this circumstance, providing additional practice for older adults would reduce (but not eliminate) the age-related differences. Note that differences in asymptotic performance due to general slowing would still result in slower performance for older adults and that the disparity in performance between younger and older adults grows with practice.

Curve 4 represents a situation in which older adults learn at the same rate as younger adults, but both the amount of learning and asymptotic levels of performance differ with age. This indicates a situation in which both the *a* and *b* parameters of the power function change with age, but the ***c*** parameter is not age sensitive. This case suggests that there was some limit on the amount of learning for older adults, but that the performance of younger and older adults improves at the same relative rate. Here again, the disparity in performance between younger and older adults grows with practice.

Finally, curve 5 represents a case in which all three parameters of the power function are age sensitive. This situation would indicate that there are differences in asymptotic performance associated with general slowing, there are age-related differences in the rate of learning, and there are age-related differences in the amount of learning. Like the two previous cases, the disparity in performance between younger and older adults increases with practice.

The curves depicted in **Figure 1** illustrate four theoretically possible age–skill relationships generated from the generalized power function. In each case, it is clear that older adults do acquire new skills, although in the latter three cases, the difference in performance between older and younger adults grows with practice. There is a good correspondence between the parameters of the generalized power function and the different phases of skill acquisition as described by Anderson. Differences in the declarative stage of skill acquisition are reflected largely in the *b* parameter (i.e., before practice, performance can be defined by the sum of the *b* and *a* parameters of the power function), the knowledge compilation phase is captured well by the *c* parameter, and the procedural phase is indexed by the asymptotic power function parameter *a*. The age-related differences in general ability, perceptual speed ability, and psychomotor ability described previously therefore suggest that each of the parameters of the generalized power function will be age sensitive. The following paragraphs review several studies that have empirically examined skill acquisition in younger and older adults. These studies generally find that older adults are able to acquire new skills, but that the amount of learning, the rate of acquisition, and the asymptotic level of performance are poorer for older adults than for younger adults.

Researchers have used a variety of laboratory paradigms to study age-related differences in the ability to learn new skills. One laboratory paradigm used to study skill acquisition involves having participants search visual displays for critical target stimuli (this is commonly referred to as a visual search task). With younger adults, practice searching for one or more consistently mapped targets leads to improvement in target detection, such that performance becomes insensitive to both the size of the target set and the number of distractors in the display. The performance of older adults also improves with consistent practice; however, their performance remains sensitive to both the size of the target set and the number of distractors in the display. These differences in performance have been interpreted as reflecting age-related differences in priority learning. With priority learning, consistently attending to a target is thought to lead to an increase in the strength of the attentional weight (i.e., priority) associated with the target, and consistently ignoring a distractor is thought to lead to a decrease in the strength of the attentional weight associated with the distractor. With practice, younger adults often report that targets appear to 'pop out' of the display, yielding highly efficient visual search performance. Fisk *et al*. reported additional evidence for age-related priority learning deficits using a reversal condition in which the mapping of prior targets and distractors was reversed after several sessions of consistent practice. Younger adults exhibited greater disruption of visual search performance in the reversal condition than older adults, providing evidence for greater priority learning in younger adults than in older adults. However, the pattern is complicated somewhat by reports from Scialfa and colleagues showing efficient

performance for both younger and older adults in feature and conjunctive visual search tasks.

The memory search task is another paradigm that has been used to study age-related differences in skill acquisition. In the memory search task, a set of items is presented for memorization. A series of probe stimuli is then presented, and the participant must decide whether each probe stimulus was one of the items in the memorized set. Younger adults improve with practice, searching memory for consistently mapped items, such that performance becomes insensitive to the number of items in the memory set. Older adults also improve with consistent practice; however, older adults do not improve as much as younger adults, and their performance improves at a rate slower than that of younger adults. These age-related differences in performance have been interpreted as differences in associative learning. According to strength theories of automaticity, when there is a consistent relationship between a stimulus and a response, the associative link between the stimulus and the response is strengthened. With high levels of practice, younger adults often report that the response comes to mind automatically without their having to think of a solution. Age-related declines in associative learning have also been reported by Salthouse, who used a continuous paired-associates procedure and found that much of the age-related impairments could be attributed to a failure to retain relevant information (i.e., encoding deficits that were correlated with age-related differences in processing speed). Similarly, Fisk and Warr reported age-related differences in associative learning that were linked to the inability of older adults to form new associations as rapidly as younger adults. An alternative retrieval-based interpretation of the age-related differences in memory search is that older adults may be reluctant to switch from inefficient rule-based processing to more efficient retrieval-based processing. The implication of this strategic difference between younger and older adults is explored in greater detail in the next section.

It is also instructive to consider the neuropsychological mechanisms underlying the age-related differences in skill acquisition (and the related declines in general, perceptual speed, and psychomotor abilities). Several neuropsychological factors have been postulated to underlie the age-related difference in skill acquisition. For example, it is well documented through magnetic resonance imaging (MRI) techniques and autopsy studies that there is a systematic decrease in brain volume with senescence. Ventricular volumes increase and temporal and frontal lobe volumes decrease with increasing age, and these changes have been correlated with declines in processing speed measures of intelligence, executive function deficits, and impairments in the early stages of skill acquisition. Using connectionist network simulations designed to evaluate differences in the network architecture and associative learning, it has been found that the amount of information that the network can learn decreases, and the amount of practice necessary to train the network increases as the number and/or connectivity of the neural-like units in the network decreases. Thus, both the rate and the amount of associative learning are predicted to decrease as a consequence of age-related brain atrophy.

Thus far, this review has indicated that older adults do not learn novel skills as proficiently as younger adults. However, as noted by Fisk and Rogers, researchers tend to use novel laboratory-based tasks to attempt to avoid confounds associated with different levels of experience in real-world tasks. A strikingly different picture emerges when performance of skills that have been practiced throughout the life span is measured. In such cases, older adults tend to perform at levels comparable to those of younger adults. For example, Salthouse studied skilled typists between the ages of 19 and 72 and found that typing speed was the same for older and younger adults, whereas the reactions of older adults were significantly slower on novel tapping and choice reaction time tasks. Clancy and Hoyer found that middle-age skilled laboratory technicians were able to search bacterial specimens as proficiently as younger adults, but that they were impaired in a novel computer-based visual search task. Similarly, Krampe and Ericsson found that the performance of older expert pianists on music-related tasks was similar to that of younger expert pianists, whereas the performance of older musicians on non-music-related tasks was significantly impaired. These authors found that the older expert pianists deliberately maintained their proficiency "by engaging in practice activities designed to improve and preserve specific aspects of their domain specific performance" (Krampe and Ericsson, 1996: 357). Finally, Strayer and Drews found that older adults exhibited the same dual-task interference as younger adults when driving an automobile and talking on a cellular telephone. By contrast, with novel dual-task combinations, older adults typically exhibit substantially greater dual-task interference. Thus, it appears that skills acquired as a younger adult that continue to receive deliberate practice over the life span are well maintained in older adults. Unfortunately, the confounding of amount of practice and age makes it difficult to determine if the sparing is due to the retention of previously acquired skills or to the additional practice that older adults have had.

Together, the data from these different methodological approaches provide clear-cut evidence for three conclusions. First, older adults can acquire new skills with consistent practice. Second, older adults do not acquire new skills as proficiently as younger adults. Third, real-world skills acquired in early adulthood that receive deliberate practice over the life span tend to be well maintained in older adults. In general, the data are most consistent with the power function represented by curve 5 in **Figure 1**: there are age-related differences in the rate of learning, there are age-related differences in the amount of learning, and there are age-related differences in asymptotic levels of performance.

Strategies and Skill Acquisition

In many instances, older adults adopt strategies that are counterproductive for acquiring new skills. For example, older adults tend to adopt a conservative response strategy emphasizing accuracy over speed to a greater extent than younger adults. That is, older adults tend to evaluate different amounts (or sources) of information before making their response. It is likely that such a strategy may interfere with learning the procedures necessary to facilitate skilled performance. Support for this interpretation comes from studies of younger adults who adopted conservative response strategies similar to older adults and exhibited sustained deficits in their skill level. Similarly, Strayer and Kramer found that differences in the performance of older and younger adults were reduced when older adults were encouraged to adopt response strategies similar to younger adults. More recently, Touron and colleagues observed that a conservative response strategy may also reduce older adults' willingness to switch processing strategies. In particular, older adults were reluctant to switch from rule-based algorithmic processing to memory/retrieval-based processing and expressed less confidence in their ability to use these memory retrieval strategies. Rogers *et al*. also reported age-related differences in strategy use, with older adults less likely to use memory retrieval strategies. Moreover, these researchers found that age-related differences in performance were reduced when analyses were restricted to those participants who used memory retrieval strategies. It may prove fruitful to identify the strategies adopted by younger adults and encourage older adults to also use these strategies.

Given that the performance of older adults does improve with consistent practice, an effective strategy for enhancing training is to encourage extensive practice on the parts of the task that are amenable to improvement. With part-task training, a task analysis is used to identify the consistent components of a task. These subtasks are practiced in isolation until performance is proficient before being integrated into the whole task. A good example of part-task training is when a musician practices a particularly difficult portion of a score several times before performing the entire piece. When the components of the subtask and the whole task are similar, transfer is expected to be good. Part-task training can be used to provide additional consistent practice for older adults so as to compensate for differences in the rate of learning new skills. For example, Dunlosky and colleagues used a variant of part-task training in which older adults were provided with self-testing techniques for identifying items that could benefit from extra practice. This self-testing procedure resulted in significant improvements in older adults' learning. However, when the demands of integrating task components are high, practicing each portion of the task in isolation may not be any more effective than practicing the whole task and in some instances may result in negative transfer if the integrated whole task goes unpracticed.

A variation on part-task training designed to avoid the limitations associated with part-task–whole-task integration is variable priority training. In variable priority training, participants always perform the whole task, but they are systematically instructed to emphasize some components of the whole task while deemphasizing the other parts of the whole task. Note that with variable priority training, the integrality of the dual-task is maintained while trainees flexibly allocate attention to the different components of the task. Kramer *et al*. compared the effectiveness of variable priority training with a fixed priority training strategy for both older and younger adults. Participants were initially trained to concurrently perform a monitoring task and an alphabet-arithmetic task and then were transferred to a scheduling and a running memory dual-task combination. Not only did variable priority training better facilitate the rate of learning and the level of mastery during the initial training period, but also older adults who received variable priority training actually outperformed younger adults who received fixed priority training. In addition, both younger and older adults showed similar transfer to novel scheduling and running memory tasks. Thus, variable priority training appears to be an effective technique for training older (and younger) adults to flexibly allocate attention in dual-task conditions.

Summary

Older adults can acquire novel skills with consistent practice. However, older adults do not learn these new skills as readily as younger adults. The observed

age-related differences in general, perceptual speed, and psychomotor abilities provide an account from the individual differences perspective of why older adults are not able to acquire skills as efficiently as younger adults. From a neuropsychological perspective, these impairments may stem in large part from brain atrophy associated with senescence. Although older adults exhibit deficits in novel laboratory-based tasks, real-world skills acquired in early adulthood that receive practice over the life span tend to be well maintained in older adults. Thus, there is an intriguing dissociation between acquisition and maintenance of skill in older and younger adults. A number of approaches can minimize the age-related differences in skill acquisition, including (1) encouraging older adults to adopt processing strategies similar to those used by younger adults, (2) providing additional consistent practice in the form of part-task training, and (3) using a variable priority training procedure to facilitate the coordination and integration of component automatic processes of skill.

See also: Assessment: Neuropsychological; Attention; Decision Making and Everyday Problem Solving; Learning; Memory; Reaction Time.

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Sleep

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Glossary

Insomnia – A repeated difficulty with sleep that occurs despite adequate time and opportunity for sleep and results in daytime fatigue. The problem may be with initiation, duration, consolidation, or quality of sleep.

Periodic Limb Movement Disorder (PLMD) – A condition of debilitating, repetitive, stereotypic leg movements occurring in non-REM sleep.

Restless Legs Syndrome (RLS) – a condition of an uncontrollable urge to move one's legs at night.

Sleep Apnea – A sleep-related breathing disorder characterized by periodic reductions in ventilation during sleep.

Introduction

Sleep problems are very common in older people. Surveys suggest that at least half of community-dwelling older people have sleep complaints and a similar number use over-the-counter or prescription sleeping medications. The 2003 National Sleep Foundation survey found that about two-thirds of older adults reported experiencing sleep problems at least a few nights a week. Sleep problems are even more common among older people in institutional settings. Age-related changes in sleep (e.g., more nighttime wakefulness, less time spent in deep sleep) are thought by many experts to reflect a decreased ability to sleep, rather than a decreased need for sleep. In addition, many comorbidities (e.g., depression, dementia) and many medications that are commonly used in older people are associated with sleep problems. Finally, certain sleep disorders (e.g., sleep apnea, restless legs syndrome, REM sleep behavior disorder) are an important cause of sleep complaints in older people. Careful assessment of the older patient with a sleep complaint is often needed to help clarify contributing factors and to identify significant sleep disorders. Referral for polysomnography is indicated if a primary sleep disorder such as sleep apnea or periodic limb movement disorder is suspected, when initial behavioral or pharmacological interventions are failing, or when violent or unusual nighttime behaviors are suspected. Management of the sleep complaint should include patient education, assessment and treatment of primary sleep disorders when warranted, identification and management of other contributing conditions, behavioral interventions, and, if appropriate and chosen carefully, pharmacological treatments.

Age-Related Changes in Sleep

Normal sleep has been characterized as two separate states, including non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep; adults normally cycle between these states over approximately 90-min intervals during the night. NREM sleep is further divided into four stages based on electroencephalographic (EEG) criteria; stages 1 and 2 are light sleep and stages 3 and 4 are deep sleep. Stage 1 sleep is characterized by relatively fast-wave EEG, and stage 2 by slowing of EEG frequency, an increase in EEG amplitude, and the appearance of sleep spindles and K complexes. Stages 3 and 4 NREM sleep are characterized by high-amplitude, low-frequency delta (slow) waves on EEG. REM sleep, sometimes referred to as paradoxical sleep, is characterized by EEG activation, muscle atonia, bursts of rapid eye movements, increased oxygen requirements, and autonomic activity and is the period when most dreaming occurs.

Commonly reported subjective and objective changes in sleep among otherwise healthy older people include more difficulty falling asleep, more nighttime wakefulness, earlier bedtime and earlier morning awakening, more daytime napping, and a decrease in stages 3 and 4 sleep (i.e., slow-wave, deep sleep). In fact, stages 3 and 4 sleep may be completely absent in very old people. Most experts believe the evidence suggests that older people have a decreased ability to sleep, rather than a decreased need for sleep. The total sleep time over 24 h either remains stable or may decrease with older age, and there is a decrease in sleep efficiency (i.e., the amount of time asleep over the time in bed). Other changes in older people include an earlier onset of REM sleep during the night, a decrease in total REM sleep, and more equal distribution of REM sleep throughout the night, as compared to the relative increase in amount of time spent in REM as the night progresses in younger people.

There also appears to be an age-associated degradation in circadian rhythms of various physiological parameters, including the sleep–wake cycle, which

may be related to neuronal loss in the internal biological clock seated in the suprachiasmatic nucleus of the anterior hypothalamus. In fact, an advanced sleep phase (e.g., feeling sleepy earlier in the evening and awakening earlier in the morning) is a common finding in older people. Various models of sleep regulation have been proposed. For example, sleep–wake pattern disturbance can be understood in terms of the two-process model of sleep regulation. A homeostatic sleep–wake mechanism (process S; i.e., the longer one is awake, the sleepier one becomes) interacts with a circadian process (process C; i.e., variability across the 24-h day where one is more alert earlier in the day than at night).

Classification of Sleep Problems

Various systems to classify sleep disorders have been developed. The International Classification of Sleep Disorders (ICSD-2) is widely recognized and was recently revised. The ICSD-2 Diagnostic and Coding Manual sorts sleep disorders into eight categories, including (1) insomnias, (2) sleep-related breathing disorders (e.g., central or obstructive sleep apnea), (3) hypersomnias of central origin not due to a circadian rhythm sleep disorder, sleep-related breathing disorder, or other cause of disturbed nocturnal sleep (e.g., narcolepsy), (4) circadian rhythm sleep disorders (e.g., advanced sleep phase disorder), (5) parasomnias (i.e., undesirable physical events or experiences at sleep onset, during sleep, or during awakening; e.g., REM sleep behavior disorder), (6) sleep-related movement disorders (e.g., restless legs syndrome, periodic limb movement disorder), (7) isolated symptoms, apparently normal variants, and unresolved issues, and (8) other sleep disorders.

The Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) (and the Text Revision, DSM-IV-TR, published in 2000) organizes sleep disorders into four major sections based on presumed etiology: (1) primary sleep disorders (dyssomnias and parasomnias), (2) sleep disorders related to another mental condition (e.g., mood disorder or anxiety disorder), (3) sleep disorders due to a general medical condition, and (4) substance-induced sleep disorder (including substances of abuse and medications).

Insomnia is the most common sleep complaint in younger and older adults. It has been variably defined over time, but the definition of insomnia provided in the ICSD-2 is a repeated difficulty with sleep that occurs despite adequate time and opportunity for sleep and results in daytime dysfunction (e.g., fatigue or malaise, inattention, daytime sleepiness). The sleeping difficulty of insomnia is generally a problem with initiation, duration, consolidation, or quality of sleep. Adults with insomnia typically complain of difficulties with initiating or maintaining sleep or, less commonly, complaints of poor-quality or non-restorative sleep. ICSD-2 lists several types of insomnia. For example, adjustment (i.e., acute) insomnia occurs in response to an identifiable stressor and is generally of a few days or a few weeks duration and, by definition (ICSD-2), lasts for less than 3 months. Psychophysiological (i.e., chronic) insomnia is defined as an insomnia that is present for at least 1 month and is characterized by conditioned sleep difficulty and/or heightened arousal in bed (e.g., excessive focus and anxiety about sleep), and the sleep disturbance is not better explained by another sleep disorder. The 2005 National Institutes of Health State-of-the-Science Conference Statement on chronic insomnia in adults recommended also defining chronic insomnia as a duration of 30 days or more of symptoms.

Evaluation of the Older Person with a Sleep Complaint

In evaluating an older person with sleep complaints, it can be particularly helpful to query whether the person primarily has symptoms of poor or unsatisfactory sleep, or excessive daytime sleepiness, and to clarify whether there is a suspicion of unusual behavior during sleep such as loud snoring, interrupted breathing, leg movements, or other unusual behaviors. The duration of the complaint is also helpful, since transient sleep problems are usually situational; persistent sleep problems are often more serious and require more detailed evaluation. In order to obtain a careful description of the sleep complaint, it may be helpful to have the patient keep a sleep log or sleep diary in which each morning he or she records time in bed, estimated amount of sleep, number of awakenings, time of morning awakening, and any symptoms that occurred during the night. Any daytime napping and use of medications should also be recorded. This should be supplemented by information from the spouse, bed partner, or others that may have observed unusual symptoms during the night. Validated sleep questionnaires are also available to help obtain additional information to guide further testing and treatment.

The sleep assessment should consider whether an underlying medical condition, substance abuse, or another mental health problem such as depression and/or anxiety is contributing to the sleep complaint. In the older adult with sleep problems, careful mental status testing is also indicated in most cases.

Evaluation should also address whether relocation, bereavement, or other acute stressors precipitated the sleep complaint. A careful review of systems should include questions about pain, nocturia, nocturnal cough, orthopnea, and other symptoms that might interrupt sleep. All medications should be reviewed, including prescription, over-the-counter, and herbal products. The focused physical examination will depend on evidence from the history. For example, a report of painful joints should be followed by a careful examination of the affected areas. A report of nighttime urination disrupting sleep should be followed by evaluation for cardiac, renal or prostatic disease, or diabetes.

Indications for Referral to a Sleep Specialist

Certain situations warrant referral to a sleep specialist for further evaluation and/or to consider diagnostic polysomnography. Polysomnography is generally performed in a sleep laboratory (but portable systems that can be performed at home are available) at night and involves the simultaneous recording of several physiological variables including EEG, electromyogram, electrooculogram, electrocardiogram, airflow at the nose and mouth, microphone for snoring, abdominal and chest respiratory effort, and pulse oximetry measurement of oxygen saturation. A daytime study to assess daytime sleepiness (e.g., the Multiple Sleep Latency Test for the diagnosis of narcolepsy and other disorders) and other studies may also be performed.

In 2005, the American Academy of Sleep Medicine published revised practice parameters on the indications for polysomnography. Based on these recommendations, referral for polysomnography is routinely indicated (1) for suspected sleep-related breathing disorders (including for diagnosis, for titration of treatment with continuous positive airway pressure, and, in some cases, for assessment of treatment results); (2) for suspected narcolepsy; (3) for evaluating sleep-related behaviors that are violent or otherwise potentially injurious to the patient or others; and (4) in certain parasomnias. The recommendations go on to state that polysomnography may be indicated in patients with neuromuscular disorders and sleep-related symptoms, to diagnose sleep disruptions thought to be seizure related, in a presumed parasomnia or sleep-related seizure disorder that does not respond to conventional therapy, or when there is a strong clinical suspicion of periodic limb movement disorder.

Additional methods to measure sleep are available, including validated sleep questionnaires, sleep logs or sleep diaries, ambulatory sleep-monitoring devices (which measure selected parameters performed during polysomnography), and wrist actigraphy (which estimates patterns of sleeping–waking based on wrist movement). A sleep specialist can also be helpful in the evaluation and management of chronic sleep complaints, even if polysomnography is not indicated.

Common Causes of Sleep Complaints in Older People

Large descriptive studies of patients of all ages referred to sleep disorder centers have generally found that insomnia was most commonly due to psychiatric illness, psychophysiological problems, drug and alcohol dependence, and restless legs syndrome, whereas excessive daytime sleepiness was most commonly due to sleep apnea, periodic limb movement disorder, or narcolepsy. However, there can be significant overlap of presenting symptoms with these disorders in older people. In addition, patients referred to sleep centers are a select population, and the most common causes of excessive sleepiness in the community are probably chronic insufficient sleep (either voluntarily or due to lifestyle schedules), or medical, toxic, and environmental conditions. However, one should not rule out a primary sleep disorder (such as sleep apnea) in the patient presenting primarily with insomnia, and likewise one should probably not refer every patient with daytime sleepiness to a sleep laboratory.

Psychiatric Disorders and Psychosocial Problems

Many studies report that psychiatric disorders are the etiology of sleep problems in over half of patients presenting with insomnia. Research suggests that sleep disturbance itself is a predictor of depression in community-dwelling older people. Even more disturbing, an analysis of data from the Established Populations for Epidemiologic Studies of the Elderly (EPESE) found that poor sleep quality was a significant predictor of suicide in older people. Sleep impairment is a common symptom in depression, in which early morning awakening is the most characteristic pattern, although other changes in sleep can be seen, such as increased sleep latency and more nighttime wakefulness. However, these changes may not be present or may be less marked in depressed individuals not seeking medical care. Conversely, sleep disturbance in older people who are not currently depressed may be an important predictor of future depression. In depressed older patients with sleep disturbance, treatment of depression may also improve the sleep abnormalities. Some studies have found changes in sleep electroencephalography

toward a more normal sleep structure with antidepressant medications, which authors suggest indicates that antidepressant drug efficacy may depend to some extent on regulation of sleep and changes in REM sleep regulation. However, some studies have found that subjective (i.e., self-report) and objective (i.e., by polysomnography) measures of changes in sleep with certain antidepressant medications do not necessarily agree.

Bereavement can also affect sleep. Bereavement without major depression may not be associated with significant changes in sleep measures, but people with bereavement plus depression have sleep patterns similar to those found in major depression. These sleep abnormalities may improve with treatment of depression. Anxiety and stress can also be associated with sleeping difficulty, usually difficulty with initiating sleep or perhaps early awakening. Patients may have difficulty falling asleep because of excessive worrying at bedtime. Research has found that older caregivers report more sleep complaints than similarly aged healthy adults. In one study, nearly 40% of older women who were family caregivers of an older adult with dementia reported using a sleeping medication for themselves in the past month.

Drug and Alcohol Dependency

Drug and alcohol use is thought to account for 10 to 15% of cases of insomnia. Chronic use of sedatives may cause light, fragmented sleep. Most sleeping medications, when used chronically, lead to tolerance of the therapeutic effects (i.e., the medication no longer helps sleep) and the potential for increasing doses. When chronic hypnotic use is suddenly stopped, there may be a rebound insomnia that leads to restarting the medication. There is some evidence that there are fewer problems with tolerance to therapeutic effects with the newer benzodiazepine receptor agonists (e.g., zolpidem, zaleplon, eszopiclone).

Alcohol abuse is often associated with lighter and shorter duration sleep. In addition, some people try to treat their sleeping difficulties with alcohol. Older people with poor sleep should be instructed to avoid nighttime alcohol, because although alcohol causes an initial drowsiness, it can impair sleep architecture later in the night. Finally, it is important to remember that sedatives and alcohol can worsen sleep apnea; these agents should be avoided in older people with documented or suspected but untreated sleep apnea.

Changes in Sleep with Dementia

Sleep disturbance is common in older people with dementia. This is likely in part related to medications and comorbidities that can also affect sleep in non-demented older people, in addition to age-related changes in sleep. In addition, there appear to be changes in sleep structure associated with dementia itself; however, the baseline slowing of EEG activity often seen with dementia can cloud the distinction between sleep versus wakefulness and various stages of non-REM sleep on polysomnography. Compared to non-demented older people, those with dementia have more sleep disruption and arousals, lower sleep efficiency, higher percentage of stage 1 sleep, and decreases in stage 3 and 4 sleep. Some authors have noted a decreased percentage of sleep spent in REM, but this has not been reported in all studies. Some studies suggest that older demented individuals actually have less sleep disturbance than older depressed people. In fact, some suggest that sleep disturbance may be an indicator of depression in older people with cognitive impairment. Disturbances of the sleep–wake cycle are common with dementia, resulting in daytime sleep and nighttime wakefulness. Sundowning, the term used to describe a worsening of confusion at night, if present, may have a neurological basis.

Medical Problems and Other Neurological Disorders

Examples of treatable medical problems that may contribute to sleep difficulty in older people include pain from arthritis and other conditions, paresthesias, cough, dyspnea from cardiac or pulmonary illness, gastroesophageal reflux, and nighttime urination. In patients with sleeping difficulties who describe pain at night, assessment and management of the painful condition is the appropriate approach. Nighttime urination may be associated with increased sleep disorders, poorer quality of sleep, nighttime thirst, and increased fatigue in the daytime.

Sleep can be impaired by certain medications taken near bedtime, such as diuretics or stimulating agents (e.g., caffeine, sympathomimetics, and bronchodilators). Certain medications can induce nightmares and impair sleep, such as some antidepressants, antiparkinson agents, certain antihypertensives (e.g., propranolol), and anticholinesterase inhibitors. Necessary sedating medications (e.g., sedating antidepressants) should be given at bedtime if possible. But all medications should be reviewed as potential culprits. For example, there is some evidence that testosterone therapy reduces total sleep time and worsens sleep apnea in older men.

There is increasing evidence of sleep abnormalities with neurological illness. Excessive daytime sleepiness is common with many neurological disorders,

such as neurodegenerative disorders and neuromuscular diseases. For example, sleep problems are common in people with Parkinson's disease. It is likely that both the pathology of Parkinson's disease and its medication treatment may contribute to sleep problems. In addition, certain parasomnias can occur in Parkinson's disease, such as REM sleep behavior disorder or vivid dreaming. Excessive daytime sleepiness is common with Parkinson's disease, with a reported prevalence of 15%. Although rare, sleep attacks have been reported as a possible manifestation of the disease or its medication treatment, but consequences can be severe.

Sleep-Related Breathing Disorders

Excessive daytime sleepiness is a common complaint in the patient with a sleep-related breathing disorder (i.e., commonly referred to as sleep apnea). This condition is characterized by periodic reductions in ventilation during sleep. Sleep apnea may be characterized as central (simultaneous cessation of breathing effort and nasal and oral airflow), obstructive (breathing effort persists without normal airflow), or mixed. In sleep laboratories, obstructive sleep apnea is more commonly diagnosed than central. Patients with obstructive sleep apnea usually present with excessive daytime sleepiness and are typically unaware of the frequent arousals associated with reductions in ventilation. Patients are often obese and may have morning headache and personality changes. Other frequently reported changes in cognition and thinking include poor memory, confusion, and irritability. There is some evidence that older people with sleep apnea have greater (negative) quality of life effects from sleep apnea compared to younger people with a similar disease severity. Other symptoms of sleep apnea that can be helpful in recognizing this syndrome and may be noted by a bed partner include loud snoring, cessation of breathing, and choking sounds during sleep. Cheynes-Stokes respiration is a form of central sleep apnea in which there is a crescendo–decrescendo respiratory pattern. This condition is more common in older people with congestive heart failure, and its presence may indicate a poor prognosis.

The reported prevalence of sleep apnea among older people varies from 20 to 70%, depending on the population studied and the specific criteria used to define sleep apnea. The lower prevalence rates are probably more valid estimates for the general aged population. The prevalence of sleep apnea increases with age, and there is an increase in the apnea–hypoponea index (AHI, a measure of sleep apnea severity) with advanced age. The importance of mild degrees of sleep-disordered breathing in older people is unclear. One study found no association between mild or moderate sleep-disordered breathing and subjective sleep–wake disturbance. The long-term consequences of asymptomatic sleep-disordered breathing in older people are also unclear. Studies suggest that milder increases in the AHI are not associated with increased mortality; however, severe increases in AHI in older people are associated with increased morbidity and mortality.

Sleep apnea is very common among patients referred to sleep centers for evaluation of daytime sleepiness. The most important predictor of sleep apnea in both younger and older adults is large body mass; however, there is not as close a relationship between obesity and sleep apnea in older people. Other risk factors include male gender and family history of sleep apnea. In addition, smoking, use of alcohol and sedative hypnotics, supine body sleeping position, sleep deprivation, medical comorbidity, and acromegaly are also associated with or may aggravate sleep apnea. The classic sleep apnea patient is the obese sleepy snorer with hypertension. Large neck circumference has also been reported as a marker for sleep apnea.

Alcoholism is an important risk factor for sleep apnea, and sleep-disordered breathing is a significant contributor to sleep disturbance in male alcoholics over age 40. Finally, there appears to be an association between sleep apnea and dementia. One nursing home study found that sleep apnea was associated with dementia, and the sleep disorder was positively correlated with the severity of dementia. However, another study concluded that sleep-disordered breathing in Alzheimer's patients is mild and not associated with mental status or behavioral changes.

Patients suspected of having sleep apnea should be referred to a sleep laboratory for evaluation, and if the diagnosis is documented, treatment. There is conflicting evidence whether older patients tolerate the main treatment of obstructive sleep apnea, nasal continuous positive airway pressure (CPAP), as well as middle-aged patients. However, research suggests that an early, positive experience with nasal CPAP may predict better patient adherence with the treatment in long-term follow-up. Research has demonstrated that CPAP can be administered successfully and tolerated even in older patients with mild to moderate dementia. Also, discomfort with a particular CPAP face appliance or interface may be improved by trying other units or devices. Unfortunately, some clinicians may not recommend nasal CPAP in older patients, perhaps due to assumptions that the treatment will not be tolerated or

successful in this population. Oral or dental devices (without CPAP) are sometimes considered for patients with mild sleep apnea or those who cannot tolerate CPAP.

Periodic Limb Movement Disorder and Restless Legs Syndrome

Periodic limb movement disorder (PLMD) is a condition of debilitating, repetitive, stereotypic leg movements may occurring in non-REM sleep and associated with disturbed sleep that is not explained by another sleep disorder. The leg movements may occur every 20 to 40 s and can last hours or even much of the night, and each movement may be associated with an arousal. The occurrence of periodic limb movements in sleep (PLMS) seems to increase with age and may or may not be associated with sleep impairment in different individuals. Whether these movements are of clinical significance has come under some recent scrutiny. One study found evidence of PLMS in over one-third of community-dwelling older people. Correlates of PLMS included dissatisfaction with sleep, sleeping alone, and reported kicking at night. Some authors have suggested that the high prevalence of PLMS with age is associated with delayed motor and sensory latencies noted on nerve conduction testing. PLMD may present as difficulty maintaining sleep or excessive daytime sleepiness, and the diagnosis is generally made based on findings during polysomnography. A bed partner may be aware of the leg movements, or these movements may remain occult until identified in a sleep laboratory.

Restless legs syndrome (RLS) is a condition of an uncontrollable urge to move one's legs at night. The symptoms can also involve the arms. The diagnosis is made based on the patient's description of symptoms, and the sleep complaint is usually difficulty in initiating sleep. Polysomnography is not needed to establish this diagnosis, which is made based on clinical presentation. There may be a family history of the condition and, in some cases, an underlying medical disorder (e.g., renal, neurological, or cardiovascular disease). The prevalence of RLS also increases with age. Many patients with RLS also have PLMS. There is some evidence that RLS symptoms in people with a low serum ferritin level may respond to iron replacement therapy.

In older patients with PLMS or RLS, dopaminergic agents are the initial agents of choice for both conditions. Nighttime doses of carbidopa/levodopa can be used on an as-needed basis for infrequent symptoms. However, chronic symptoms are best treated with a dopamine agonist (e.g., pramipexole or ropinirole), which may be given about 2 h prior to bedtime. Some patients may describe a shift of their symptoms to daytime hours with successful treatment of symptoms at night. Benzodiazepines or opiates have also been used for these conditions but may carry greater risk of side effects in older people.

Disturbances in the Sleep–Wake Cycle

Disturbances in the sleep–wake cycle may be transient, as in jet lag, or associated with an obvious cause, as in shift work. Some patients have persistent disturbance with either a delayed sleep phase (fall asleep late and awaken late) or an advanced sleep phase (fall asleep early and awaken early). The advanced sleep phase is particularly common in older people. Some patients have persistent sleep phase disturbance, in which circadian rhythms and sleeping period have become completely desynchronized (e.g., people who are always asleep during the day and awake at night), or have irregular sleep–wake cycles and very disjointed sleep habits.

It is unclear to what degree that changes in sleep pattern in older people (such as increased daytime napping and disrupted nighttime sleep) are due to alterations in circadian rhythms. Results have been mixed, but several studies have shown age-related decreases in hormonal levels and evidence of earlier circadian rises in certain hormones, suggesting age-related alteration in circadian rhythm. Problems related to an advanced sleep phase may respond to appropriately timed (i.e., evening) bright light exposure. Patients with a significant sleep phase cycle disturbance should be referred to a sleep laboratory for evaluation. Dementia and delirium may also cause sleep–wake disturbance, in addition to increased nighttime awakenings, nighttime wandering, and nighttime agitation.

REM Sleep Behavior Disorder

REM sleep behavior disorder is characterized by excessive motor activities during sleep, with the pathological absence of the normal muscle atonia during REM sleep. The presenting symptoms are usually vigorous sleep behaviors associated with vivid dreams, with injury to the patient or their bed partner. The condition may be acute or chronic and is more common in older men, and there may be a family predisposition. Reported cases of acute transient REM sleep behavior disorder have been primarily drug induced (e.g., antidepressant medications, caffeine) or related to drug withdrawal. The chronic form of REM sleep behavior disorder may be idiopathic or associated with a neurological abnormality

(e.g., Parkinson's disease) or psychiatric illness. Polysomnography is recommended to establish the diagnosis of REM sleep behavior disorder. Clonazepam is reported to be highly effective for the treatment of REM sleep behavior disorder, with little evidence of tolerance or abuse over long periods of treatment. Alternatively, there is some evidence for the use of melatonin for REM sleep behavior disorder in older patients with underlying Parkinson's disease. Environmental safety interventions are also indicated, such as removing dangerous objects from the bedroom, putting cushions on the floor around the bed, protecting windows, and, in some cases, putting the mattress on the floor.

Sleep Disturbance in the Nursing Home Setting

Studies of sleep in nursing home residents have demonstrated marked disruption in sleep with frequent arousals during the night and excessive daytime sleeping. In addition, sleep-related problems are a common reason for institutionalization. Up to 70% of caregivers report that nighttime difficulties played a significant role in their decision to institutionalize their older loved one, often because the sleep of the caregiver was being disrupted. Once in the nursing home, many residents sleep during much of the day and have frequent awakenings during the night. One study found the average duration of sleep episodes during the night in nursing home residents to be only 20 min. Another study found that 65% of residents reported problems with their sleep and hypnotic use was common, but there was no association between sedative/hypnotic use and the presence, absence, or change in sleep complaints after 6 months of follow-up. Common conditions in nursing home residents that may contribute to these sleep difficulties include multiple physical illnesses, psychoactive medications, debility and inactivity, increased prevalence of sleep disorders, and environmental factors such as nighttime noise, light, and disruptive nursing care activities. Lack of bright light exposure during the day may also be a factor, and there is some evidence for improvement in circadian rhythms of activity with bright light exposure in demented older nursing home residents. Non-pharmacological and environmental interventions can be effective in decreasing excessive daytime sleeping but have had modest effect on nighttime sleep parameters in this setting.

Management of Insomnia in Older People

The appropriate treatment of sleep problems must be guided by knowledge of likely etiologies and potential contributing factors. It is not appropriate to start an older person with sleep complaints on a sedative/hypnotic agent without a careful clinical assessment to identify a likely cause of the sleep complaint. Most sedative/hypnotics, particularly benzodiazepines, have a documented association with falls, hip fracture, and daytime carryover symptoms in older people. Newer non-benzodiazepine hypnotics seem to have a better profile than older benzodiazepines and have been studied in healthy older people, but have not been studied in frail older people with significant comorbidity. If the initial history and physical examination do not suggest a serious underlying cause for the sleep problem, a trial of improved sleep hygiene and behavioral interventions is usually the best first approach (see **Tables 1** and **2**). If the patient takes daytime naps, it is important to clarify whether these are needed rest periods or if they are due to inactivity, boredom, or sedating medications. It is important to explain to the patient that daytime naps and dozing will decrease nighttime sleep.

Short-term hypnotic therapy may be appropriate in conjunction with improved sleep hygiene in some

Table 1 Commonly recommended sleep hygiene measures to improve sleep

Maintain a regular rising time
Maintain a regular sleeping time, but do not go to bed unless sleepy
Decrease or eliminate naps, unless necessary part of sleeping schedule
Exercise daily, but not immediately prior to bedtime
Use bed for sleeping or intercourse only, i.e., do not read or watch television in bed
Relax mentally prior to sleep, do not use bedtime as worry time
If hungry, have a light snack before bed (unless there are symptoms of gastroesophageal reflux or medically contraindicated) but avoid heavy meals at bedtime
Limit or eliminate alcohol, caffeine, and nicotine, especially prior to bedtime
Wind down prior to bedtime and maintain a routine period of preparation for bed (e.g., washing up, going to the bathroom)
Control the nighttime environment with comfortable temperature, quiet, and dark
Trial of a familiar background noise, e.g., fan or other appliance or a white noise machine
Wear comfortable bed clothing
If unable to fall asleep within 30 min, get out of bed and perform a soothing activity such as listening to soft music or light reading (but avoid exposure to bright light during these times), then return to bed when sleepy
Get adequate exposure to bright light during the day

Table 2 Examples of behavioral interventions to improve sleep

Intervention	*Goal*	*Description*
Stimulus control therapy	To recondition maladaptive sleep-related behaviors	Patient instructed to go to bed only when sleepy; use the bed only for sleep or intercourse (not for eating or watching television); get out of bed if unable to fall asleep; return to bed only when sleepy; get up at the same time each morning; do not take naps during the day
Sleep restriction therapy	To improve sleep efficiency (time asleep over time in bed) by causing sleep deprivation	Patient first collects a 2-week sleep diary to determine average total daily sleep time; patient stays in bed only for that duration plus 15 min; get up at same time each morning; no napping during the daytime, gradually increase allowed in-bed time as sleep efficiency improves
Cognitive interventions	To change misunderstandings and false beliefs regarding sleep	Patient's dysfunctional beliefs and attitudes about sleep are identified; patient is educated to change these false beliefs and attitudes, including normal changes in sleep with increased age and changes that are pathological
Relaxation techniques	To recognize and relieve tension and anxiety	In progressive muscle relaxation, patient is taught to tense and relax each muscle group in a systematic way. In electromyographic biofeedback, the patient is given feedback regarding muscle tension and learns techniques to relieve this tension. Meditation or imagery techniques are taught to relieve racing thoughts or anxiety
Cognitive-behavioral therapy	Combines therapies to improve symptoms of insomnia	Cognitive-behavioral therapy includes various combinations of both cognitive as well as behavioral interventions. As noted above, the cognitive component is aimed at changing patients' dysfunctional beliefs and attitudes about sleep, and the behavioral component may include therapies such as stimulus control therapy, sleep restriction, or relaxation training. Sleep hygiene education is often also included

cases of transient, situational insomnia, particularly during bereavement, acute hospitalization, and other periods of temporary acute stress. The clinician should not withhold appropriate hypnotic medication treatment in situations in which it is clearly indicated, as long as the clinician has addressed the potential risks and benefits, particularly in older people who are frail. In chronic insomnia, it is imperative that the clinician rule out primary sleep disorders and review medications and other medical conditions that may be contributory. In the patient with symptoms of chronic insomnia, sedative/hypnotic agents should be considered cautiously in the older patient because of the potential complications associated with long-term use of these agents. However, some sleep experts believe that evidence suggests that the newer non-benzodiazepine hypnotics are much safer than older benzodiazepines when used chronically; adequate research to address this question in frail older patients is not yet available.

Non-pharmacological Interventions to Improve Sleep in Older People

Measures to improve sleep hygiene are often recommended, but effectiveness may be modest (see **Table 1**). However, several controlled trials have shown that other behavioral interventions can be quite effective in improving insomnia in older people (see **Table 2**). Several studies of behavioral interventions in community-dwelling older people with insomnia concluded that these interventions produce reliable and durable therapeutic benefits, including improved sleep efficiency, sleep continuity, and satisfaction with sleep; treatment is also helpful in reducing chronic hypnotic use. Stimulus control and sleep restriction therapy, which focus on improving poor sleep habits, can be very effective in older people. Cognitive and educational interventions are also important in changing inaccurate beliefs and attitudes about sleep. Research suggests that sleep benefits from behavioral interventions are sustained over the long term, and patients often prefer behavioral to pharmacological interventions. Several randomized controlled trials have demonstrated that behavioral therapies, particularly cognitive-behavioral therapy (which combines cognitive therapy with aspects of other behavioral interventions such as sleep restriction and stimulus control therapy), are effective in improving sleep problems in older people with insomnia that is either primary or associated with comorbid conditions. The cognitive-behavioral model for insomnia posits that a precipitating factor (e.g., stress, illness) initially disrupts sleep, and perpetuating factors (e.g., maladaptive behaviors such as excessive time in bed, frequent dozing during the day, and false beliefs about sleep) maintain sleep disturbance long after the precipitating event resolves. Cognitive-behavioral strategies address these issues, for example, sleep restriction (reducing time in bed

to approximate total sleep time) and correcting inappropriate thoughts about sleep (e.g., "spending more time in bed will help me to sleep better"). A major limitation to use of these behavioral interventions has been lack of expertise among providers, but limited primary care friendly versions of these interventions are under development and may prove useful.

Several small studies have tested the effectiveness of bright light exposure (generally provided by commercially available light boxes; however, sunlight exposure may also be effective) on sleep in older insomniacs. Positive effects on sleep have been demonstrated with light exposure of various intensities for various durations and at various times during the day, but the timing of exposure should be based on the underlying condition. Evening bright light exposure seems to be particularly useful in the older person with an advanced sleep phase (i.e., the person goes to sleep early and wakes up early), whereas early morning bright light exposure is potentially useful for a delayed sleep phase (i.e., the person goes to sleep late and wakes up late). One author recommends that older people with sleep maintenance insomnia should be treated with 2 h of bright light exposure, equal to the amount of outdoor light found at mid-day or artificial bright light of at least 2500 lux in the evening. However, even short durations of bright light have been shown to improve sleep complaints in healthy older people. A routine eye examination is recommended prior to bright light treatment, and one should avoid light boxes with UV exposure. There is also a growing literature suggesting beneficial effects (in terms of sleep patterns and circadian rhythms of activity) of bright light therapy in demented nursing home residents with disturbed sleep.

Other interventions may also be helpful. For example, bathing before sleep has been demonstrated to enhance the quality of sleep in older people, perhaps related to an increase in body temperature with bathing. In addition, exercise has been studied as a possible intervention to improve sleep. Moderate-intensity exercise has been shown to improve sleep in healthy, sedentary people aged 50 and older with moderate sleep complaints at baseline. But rigorous exercise right before bedtime may interfere with sleep. A randomized controlled trial demonstrated that older adults with moderate sleep complaints had improvement in self-reported sleep quality with a 6-month, low- to moderate-intensity tai chi program.

Non-pharmacological interventions on sleep have also been studied in institutional settings. A study in institutionalized demented residents with sleep and behavior problems found that morning bright light exposure was associated with better nighttime sleep and less daytime agitation. Another study of nursing home residents with dementia and behavioral problems found that a program of social interaction with nurses was effective in reducing behavioral problems and sleep–wake rhythm disorders in 30% of the subjects. A small trial in incontinent nursing home residents demonstrated increased nighttime percent sleep and less agitation among nursing home residents randomized to receive a combined daytime physical activity program plus nighttime intervention to decrease noise and light disruption in residents' rooms. In a larger sample, a similar multimodal intervention combining these interventions with daytime bright light exposure (sunlight) and a bedtime sleep routine demonstrated decreased daytime sleeping as the major sleep outcome. Another trial combining an enforced schedule of structured social and physical activity for 2 weeks in a small sample of assisted living residents found that treated residents had enhanced slow-wave sleep and improved performance in memory-oriented tasks compared to controls.

Non-pharmacological interventions may also be important in the acute hospital setting. A large study testing the feasibility of a non-pharmacological sleep protocol for hospitalized older patients (consisting of a back rub, warm drink, and relaxation tapes) administered by nursing personnel was successful in reducing sedative/hypnotic drug use and had a stronger association with improved quality of sleep than sedative/hypnotic drugs.

Pharmacotherapy for Sleep Problems in Older People

Benzodiazepine receptor agonists (including benzodiazepines such as temazepam and estazolam, and non-benzodiazepine hypnotics such as zolpidem, zaleplon, and eszopiclone) are the most commonly suggested agents for sleep in older people (see **Table 3**). These medications should be used as briefly as possible, and all (except eszopiclone and modified release zolpidem) have an FDA indication for short-term treatment of insomnia that mentions that hypnotic use should generally be limited to 7 to 10 days of use, and re-evaluation of the patient is recommended if these agents are to be taken for more than 2 to 3 weeks. Care should be taken to avoid dependence on these medications, since continued use results in tolerance with many of these agents and may result in increasing dosages. Imbalance (and increased risk of falls), daytime sedation, and cognitive effects are all particular concerns in using sleeping pills in older people. However, there is some evidence that insomnia itself may increase risk of falls.

Table 3 Examples of hypnotic medications

Drug	*Class*	*Starting dose*	*Usual dose*	*Half-life*
Temazepam	Intermediate-acting benzodiazepine	7.5 mg	7.5–30 mg	8–10 h (can be as long as 20–30 h in elderly)
Estazolam	Intermediate-acting benzodiazepine	0.5–1.0 mg	0.5–2.0 mg	12–18 h
Zolpidem	Non-benzodiazepine, imidazopyridine (short-acting)	5 mg (6.25 mg for modified-release formulation)	5–10 mg (6.25–12.5 mg for modified-release formulation)	2.5 h (range 1.4–4.5 h; longer in liver disease); reported half-life for modified-release formulation is 2.5–2.8 h
Zaleplon	Non-benzodiazepine, pyrazolopyrimidine (short-acting)	5 mg	5–10 mg	1 h (reportedly unchanged in elderly)
Eszopiclone	Non-benzodiazepine, pyrrolopyrazine derivative	1 mg	1–3 mg (2 mg max in elderly)	6 h
Ramelteon	Melatonin receptor agonist	8 mg	8 mg	1–2.6 h (active metabolite 2–5 h)

Different hypnotics seem to vary in the extent to which these potentially serious side effects occur, but the cautious clinician should assume that any of these agents may cause these effects to some extent, particularly in older patients who are frail. For example, increased body sway (as measured by clinical stabilometric platform tests) occurred with all three hypnotic agents tested in one study of the acute effects of hypnotics (including a newer, non-benzodiazepine hypnotic), although the effects disappeared more quickly with the shorter-acting agent.

Short-acting benzodiazepines are recommended for problems initiating sleep, and intermediate-acting agents are recommended for problems with sleep maintenance. Short-acting agents appear to be less likely to be associated with falls and hip fractures. However, agents with rapid elimination in general also produce the most pronounced rebound and withdrawal syndromes after discontinuation of the agent. Rebound insomnia after cessation of short-acting agents is dose dependent and can be reduced by tapering the dosage prior to discontinuing the drug. The short-acting benzodiazepine triazolam has been associated with nocturnal amnesia and confusion in older people and is therefore generally not recommended for this population.

Intermediate-acting agents have less association with daytime drowsiness than long-acting agents. If the patient also has difficulty falling asleep, these agents should be given 30 min before bedtime. Temazepam has an intermediate half-life and no known active metabolites, and its metabolism is not thought to be affected by aging. However, daytime sedation may occur with this agent. Estazolam is a benzodiazepine with rapid onset and intermediate duration of action, so it may be effective in both initiating and maintaining sleep. This agent has slightly active metabolites, and some accumulation may occur. The most common adverse effects are somnolence and hypokinesia. Estazolam is thought to have little effect on daytime psychomotor performance.

Long-acting benzodiazepines such as quazepam and flurazepam (which has an active metabolite with a half-life of more than 100 h in older people) should not be used in older people because of associated daytime sedation, lethargy, ataxia, falls, and cognitive and psychomotor impairment. The use of shorter-acting agents seems to greatly reduce the frequency of these effects.

Three non-benzodiazepine hypnotics available include zolpidem, zaleplon, and eszopiclone. Although these agents are structurally unrelated to the benzodiazepines, they share some of the pharmacological properties of benzodiazepines and have been shown to interact with the central nervous system GABA receptor complex at benzodiazepine (GABA-BZ) receptors. The selectivity of these newer agents to the GABA-BZ receptor may account for the decreased muscle relaxant, anxiolytic, and anticonvulsant effects compared with benzodiazepines in some studies. All three agents have been tested in healthy older people and appear to have low potential for tolerance, abuse, or dependence. As with most other hypnotics, these agents have not been well studied in very frail or very old people. Despite evidence of greater safety with use of these newer agents, there is still considerable debate over the risks and benefits of these agents in older people (particularly those who are frail).

Zolpidem is a non-benzodiazepine imidazopyridine that has been studied in older insomniacs. It is available in 5 mg and 10 mg tablets. Studies suggest that in older patients, zolpidem does not produce rebound insomnia, agitation, or anxiety with cessation; does not seem to produce impaired daytime

performance on cognitive and psychomotor performance tests; and the therapeutic effect may outlast the period of drug treatment. Zolpidem is a short-acting hypnotic. A modified-release formulation of zolpidem is also available (recommended doses of 12.5 mg for adults and 6.25 mg for elderly). It is marketed as an agent that can improve sleep onset and sleep maintenance; however, the clinical differences between these formulations appear rather modest.

Zaleplon is a non-benzodiazepine hypnotic from the pyrazolopyrimidine class that has also been studied in older insomniacs for short-term use. It is available in 5 mg and 10 mg tablets. Because of its rapid onset of action and short half-life, zaleplon should be taken immediately prior to bedtime (e.g., kept securely in a bedside table) or may be taken after the patient has gone to bed and has been unable to fall asleep.

Eszopiclone is the S isomer of zopiclone, which has been available as a hypnotic in countries outside the United States for many years. It is recommended at an initial dose of 1 mg for older patients; patients with difficulty staying asleep may need a 2 mg dose. Although a 3 mg dose of eszopiclone is available, recommendations suggest that the dose does not exceed 2 mg in older people. Ingestion of a heavy or high-fat meal with eszopiclone may slow the absorption and reduce effects of the drug. An unpleasant taste in the mouth has also been reported with this drug. The manufacturer of eszopiclone sponsored a 6-month trial that suggested that there was no tolerance to the hypnotic effects and no withdrawal symptoms after up to 6 months of therapy. For this reason, in the United States, eszopiclone has been approved for use without a limit on the duration of therapy.

Low doses of sedating antidepressants (e.g., trazodone, doxepin, and mirtazapine) at bedtime have been used by some clinicians as a sleep aid (off-label use), particularly in patients with depression (off-label use). Low-dose trazodone at bedtime has been studied as a nighttime adjuvant for sleep in depressed patients receiving another antidepressant at therapeutic doses during the daytime, but there has been little other study of this and other antidepressants used as a hypnotic. Daytime carryover and sedation, particularly with long-acting agents such as mirtazapine, may be a significant problem in some older people. Situations where one might consider off-label use of low-dose sedating antidepressants for sleep include patients who have had problems with benzodiazepine receptor agonists, people with fibromyalgia, or those with a history of substance abuse for whom there is concern about use of a benzodiazepine receptor agonist.

A melatonin receptor agonist, ramelteon, is also available for insomnia and is approved for use to improve difficulty falling asleep. Ramelteon (available in an 8 mg dose) is highly selective for melatonin receptors type 1 (which in animal models may regulate sleepiness) and type 2 (which may mediate the phase-shifting effects of melatonin on the 24-h biological clock). Ramelteon was approved by the FDA without a time restriction for duration of use. The hypnotic effects of ramelteon appear to be modest. In addition, it may increase serum prolactin levels, but the significance of this finding is unclear. Ramelteon has been tested in older patients with insomnia. Ramelteon is not a controlled substance and does not have abuse potential. Its role in the management of sleep complaints in older people has not yet been clarified.

Chronic Hypnotic Use

Studies suggest that the bulk of prescription hypnotic use is occurring among chronic users, rather than for transient or short-term insomnia. In addition, chronic use of hypnotics appears to be more common in older adults than in younger adults, and more common in women than in men. Several older studies have shown evidence for increased morbidity and mortality with chronic use of sleeping pills. Epidemiological evidence suggests that there is an increased risk of falls and hip fracture with use of benzodiazepines. However, there is debate among sleep experts over the risks of chronic hypnotic use, particularly with the availability of the newer, non-benzodiazepine hypnotics. Some studies suggest that insomnia, separate from hypnotic use, may also be a risk factor for falls in older people. Regardless of these controversies, it is likely prudent for the clinician to consider helping older chronic hypnotic users to reduce their use of these agents, particularly when there is evidence of adverse side effects. Studies suggest that protocols to taper the hypnotic dose slowly, substitution of the nightly pill ritual, and behavioral interventions (e.g., cognitive-behavioral therapy) may help reduce or eliminate prescription hypnotic use.

Non-prescription Sleeping Agents

Nearly half of older people report using non-prescription sleeping products. The most frequently used products are sedating antihistamines, acetaminophen, alcohol, and melatonin. Sedating antihistamines (e.g., diphenhydramine) are common ingredients in over-the-counter sleeping agents as well as combination analgesic–sleeping agents that are marketed for nighttime use. Diphenhydramine

has potent anticholinergic effects and tolerance develops after several weeks, and use of these agents is strongly discouraged for older people by most geriatricians. Patients with mild discomfort and sleeping difficulties may have adequate relief with a simple pain reliever (e.g., acetaminophen) at bedtime, rather than risking side effects with the combination agent. As mentioned previously, although alcohol causes some initial drowsiness, it can interfere with sleep later in the night and may actually worsen sleeping difficulties.

Evidence is mixed regarding the effectiveness of melatonin as a treatment for insomnia. There is some evidence in older people with insomnia that melatonin administration decreases sleep latency (time to fall asleep) and wake time after sleep onset, and increases sleep efficiency (time asleep over time in bed). However, a small trial in which subjects over 55 years of age with sleep maintenance insomnia were treated with either transbuccal melatonin or placebo did not find polysomnographic evidence of improved sleep. Other research has suggested that older people with insomnia who also have low melatonin levels (e.g., as measured by urinary 6-sulfatoxymelatonin) may be more likely to respond to melatonin replacement therapy. Because of these mixed results and the lack of regulative control in the currently available melatonin products, it is difficult for the clinician to recommend use of these products. However, there is evidence for use of melatonin in blind people with a disturbed sleep–wake cycle and in jet lag and shift workers. Valerian is a herbal product with several active compounds that causes mild sedation of unknown mechanism. Some tested products labeled as valerian had little or no valerian, and it should probably not be recommended because of inadequate study and lack of regulation. One study found valerian no different from placebo on measures of sedative effects.

See also: Alcohol and Drugs; Bereavement and Loss; Dementia; Frail Elderly; Long Term Care.

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Slowing of Aging

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Glossary

Free Radical Theory of Aging – Theory that postulates that metabolic activities involving oxygen create toxic reactive oxygen species that damage cells.

Hormesis – The anti-aging and longevity promoting effects resulting from the cellular response to mild repeated stress.

Molecular Chaperones – Proteins involved in folding newly made proteins and that repair the potential damage caused by misfolding under stressful conditions.

Introduction

The ability to slow the aging of an organism in a laboratory is now commonplace. Prior to the late 1980s, the only reproducible demonstration of slowed aging was the caloric restriction of rodents. Genetic selection and recombinant inbred line generation in model organisms gave the first insights into the genetic basis of life span, but the identification of the single gene mutations that extended life span in the nematode *Caenorhabditis elegans* resulted in a vast expansion of the aging field during the 1990s. It is now trivial to extend the life span by genetic or environmental manipulations in the fruit fly, the nematode, and budding yeast. Although, mechanisms of aging remain poorly characterized, a wealth of information has become available from these systems, and as a result, long-lived mouse models are being created and studied. Early indications are that the life span of diverse species, including mammals, is influenced by similar genetic and environmental interventions.

Genetic Determination of Life Span

Aging is a non-adaptive trait that has arisen because long-term maintenance is not necessarily a feature of optimal fitness. The action of genes on aging is therefore either through enhancing maintenance functions or reducing or postponing a major cause of death. In contrast to programmed cell death, aging mechanisms have not evolved to cause organismal death but rather are the indirect effects of selection on early life traits.

Many hundreds of genes have been identified that when altered by mutation or overexpression extend life span by slowing aging in the budding yeast *Saccharomyces cerevisiae*, the nematode *C. elegans*, and the fruit fly *D. Melanogaster*. The genes encode proteins involved in a large variety of different processes, including development, reproduction, metabolism, intracellular signaling, and endocrine signaling. A few prominent examples are discussed here.

Insulin/IGF-1 Signaling Determines Life Span

During the past years, classical studies have revealed a key role of insulin or insulin-like growth factor-1 (IGF-1) signaling in the life span of several organisms from yeast to rodents. This suggests that the physiological processes controlled by these hormones are conserved and influence common aging mechanisms in a wide variety of species. While a sustained blockade of insulin receptor pathways can be detrimental, less severe modulation may positively affect human life span. Work has begun to address whether genetic variation impacting on insulin/IGF-1 signaling in human populations affects life span.

Mammalian Insulin/IGF Signaling

Since its discovery in 1921, the vast majority of studies have focused on the role of insulin in glucose homeostasis and general metabolism. Interestingly, the two main pathologies related to this hormone, obesity and diabetes, have been also associated with a decrease in life expectancy. It has been also reported that human centenarians have an exceptional insulin sensitivity and a reduced incidence of diabetes.

Insulin (from Latin *insula*, 'island', because it is produced by the β cells in the Islets of Langerhans in the pancreas) is a polypeptide hormone that bears homology to the insulin-like growth factors (IGF-I and IGF-II), a family of hormones/growth factors that regulate metabolism, growth, cell differentiation, and survival of most tissues in mammals. These effects are mediated by the insulin receptors (IRs) and type 1 IGF receptors (IGFRs) that initiate their action through a highly conserved signaling system. The receptors are tyrosine kinases. Insulin and/or IGF-I/II ligand binding to the receptors causes dimerization and activation of the cytoplasmic kinase domain, producing an autophosphorylation on tyrosine residues. This phosphorylation produces conformational modifications that

allow receptors to bind intracellular substrate proteins. At least 10 intracellular substrates, also named adaptor proteins, for the insulin and IGF-1 receptors have been identified in mammals, and the best characterized are the four insulin receptor substrate (IRS) proteins. In addition, adaptor proteins contain an amino-terminal PH (pleckstrin homology) domain and several phosphotyrosine motifs that serve as binding sites for SH2 (Src-homology 2) domain-containing proteins. Two important SH2 molecules related to the insulin action are the enzyme phosphatidylinositol 3-kinase (PI 3-kinase) and the adaptor molecule Grb2. PI 3-kinase is the link between IR and the metabolic effects of the hormone by activating Akt/protein kinase B (PKB) and protein kinase C (PKC), which produces the activation of p70 S6 K and glycogen synthase kinase 3 (GSK3). This generates a glycogen/lipid stimulation, protein synthesis, and glucose transporter translocation to the plasma membrane with a consequent increase in glucose transport. Meanwhile, Grb2 links the hormone action to the Ras-MAP kinase pathway and is critical for the ability of insulin to stimulate cell growth and differentiation.

Insulin Signaling in Simple Organisms

During the past two decades *C. elegans* has become one of the most popular model systems for gerontological research. A primary advantage of the system is the short 20-day life span and a wealth of genetic resources.

Mutations that increase longevity were first identified in this nematode in a classical study looking for long-lived mutants carried out by Klass in 1983. Later analysis of the long-lived mutants by Thomas E. Johnson revealed that a single gene was responsible for the observed 70% life span extension. The gene, *age-1*, was later cloned in Gary Ruvkun's laboratory and identified as the nematode homologue of the p110 phosphoinositode-3-OH kinase (PI3 K) that is able to generate 3-phosphoinositides, including phosphatidylinositol-3,4-biphosphate ($PI(3,4)P_2$) and phosphatidylinositol-3,4,5-triphosphate ($PI(3,4,5)P_3$). These second messengers activate the PDK-1 and AKT-1 and AKT-2 kinases. Worm orthologs of these genes were identified and shown to affect life span.

Cynthia Kenyon's laboratory made the observation in 1993 that the *daf-2* mutation in *C. elegans* increases life span by approximately 100%. *daf-2* is upstream of *age-1* and encodes an insulin/IGFR, suggesting that reducing the activity of the insulin signaling pathway increases longevity in this nematode. DAF-16, a forkhead transcription factor, is a downstream target of the AKT signaling and is a key molecule for the influence of insulin/IGF-I-like metabolism on longevity (**Figure 1**). All life span extending mutations identified in the insulin/IGF-I pathway require functional DAF-16 activity, including mutations in *age-1* and *daf-2*. Thirty-seven insulin-like genes have been reported in this animal model. It has been shown that life span may be influenced in a tissue-specific way and that the nervous system and the intestine could play a major role in determining the rate of aging.

In *Drosophila melanogaster*, seven insulin-like peptide (dilp) genes have been reported. Three of these genes are expressed in two paired clusters of seven neurosecretory cells in the brain that send axonic projections to the corpora cardiaca, a component of the principal endocrine gland, and to the aorta, where these peptides are released into the insect blood, the hemolymph. Selective ablation of these neurosecretory cells produces a significant reduction in body size. Interestingly, the expression and release of these peptides are regulated by hemolymph glucose levels, suggesting that these cells could be functionally equivalent to the pancreatic β cells in mammals. Consistent with this, a hormone related to glucagon called adipokinetic hormone is produced by cells in the corpora cardiaca, and its release is similar to the glucagon release from pancreatic β cells.

Recently, some lines of *Drosophila* displaying extended longevity have been reported. The *Drosophila*

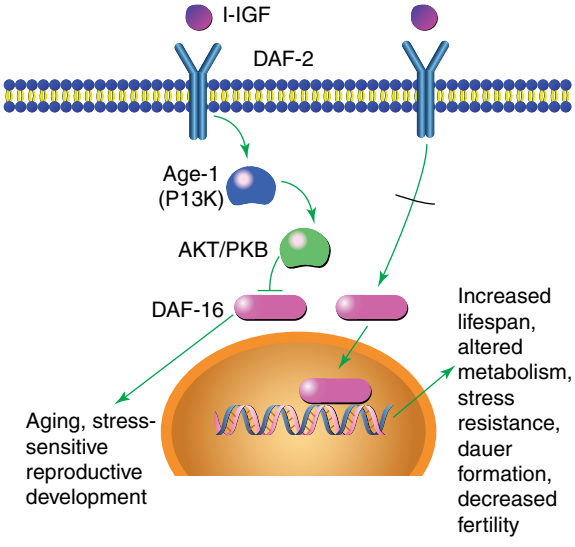

Figure 1 I-IGF control of life span in the nematode *C. elegans*. After insulin or insulin-like peptides bind the insulin-like receptor DAF-2, it undergoes autophosphorylation and catalyzes the phosphorylation of several proteins, resulting in the activation of PIK3-Akt signaling pathway. Akt phosphorylation of the forkhead-like transcription factor DAF-16 inhibits the translocation of this factor to the nucleus, eliciting aging and stress sensitivity and maximal reproductive development. Inhibition of this pathway produces an increase in stress resistance and life span but decreases fertility through the translocation and activation of DAF-16.

insulin-like receptor (InR) is homologous to mammalian insulin and IGF-1 receptors, as well as to *daf-2*. Mutation of InR in the fly significantly extends adult longevity. Females with an InR heteroallelic hypomorphic genotype are small and infertile and live 85% longer than wild-type. Mutation of the IRS homologue *chico* also increases adult maximum life span of *Drosophila* females by around 41%. Experiments involving genetic rescue of the effects of *chico* on somatic growth in transgenic flies and crosses with flies heterozygous for a dominant mutation causing female sterility have provided evidence that neither the dwarf phenotype nor infertility is required for the increased longevity of *chico* minus flies.

Another single mutation of the gene named *Indy* ('I'm not dead yet') was found to extend the heterozygote life span in *Drosophila*. This gene encodes a homologue of the mammalian sodium dicarboxylate cotransporter, a protein that seems to be critical for energy supply, metabolite absorption, and intermediary metabolism. This suggests that this mutant could be under a caloric restriction process that could contribute to the increased life span observed.

Mutation in the *methuselah* gene produces an increase of 35% in life span and also confers resistance to a variety of stressors (e.g., heat shock, starvation, and oxidative stress). The *methuselah* gene encodes a novel G-protein-coupled receptor; however, the mechanism triggered by this gene in order to increase *Drosophila* life span remains unclear.

The homologue of mammalian FOXO and *C. elegans* DAF-16, dFOXO, has been identified in *Drosophila*. Expression of this gene during larval development produces a decrease in larval growth and some alterations in feeding behavior that lead to a reduction in adult body size due to decrease in cell size and in the total amount of cells. Interestingly, this phenotype may be rescued by coexpression of dPI 3-kinase and dAkt, two upstream insulin signaling components. Activation of dFOXO in the adult pericerebral fat body of *Drosophila* is sufficient to increase both male and female life span, to increase resistance to oxidative challenge, and to alter whole-animal lipid metabolism.

Insulin Signaling in the Mouse

Blüher and colleagues have generated a mouse with a mutation of the IR gene in adipose tissue (FIRKO mice) reducing IR by 85–90% in the adipose tissue alone. FIRKO mice present an increase of nearly 18% in median and maximum life span as compared to wild-type littermates. This study suggests a correlation between reduced insulin signaling in adipose tissue and increased life span. Mice null for IGF-1R are not viable and die at birth. However, Holzenberger and colleagues have produced the mice heterozygous for the IGFR gene ($Igf1r^{+/-}$) and showed several phenotypic similarities with the *daf-2* mutants of *C. elegans*, in which the function of the insulin/IGF-1-like receptor is lost. Data pooled from males and females indicate that the $Igf1r^{+/-}$ mice have a mean life span that is 26% longer than that of wild-type mice. Female $Igf1r^{+/-}$ mice present a statistically significant increase of 33% in mean life span as compared to female wild-type mice. However, the increase (16%) in the life span of male $Igf1r^{+/-}$ mice is not statistically significant, probably due to a glucose intolerance developed in males.

These results provide the first evidence that reduced function in insulin and/or IGF-1 signaling pathways produces an increased life span in mammals. Thus, modulators of aging processes in organisms as evolutionarily distant as invertebrates and mammals may be mediated, at least partially, through a similar hormone signaling pathway.

Life Span Extension by Enhanced Stress Resistance

There is a causal relationship between resistance to stress and longevity in several animal models. Almost all animal models respond to acute stress by synthesizing stress proteins. For example, heat shock results in the upregulation of genes encoding members of the heat shock protein (HSP) family, many of which exhibit chaperone functions that protect the organism against thermal stress. Other forms of stress, including oxidative stress, also induce the heat shock response. All known long-lived mutants exhibit increased resistance to environmental stresses, such as oxidative stress, heat shock, UV irradiation, and heavy metal stress. Several manipulations that enhance stress tolerance in *C. elegans* also result in longevity (see **Figure 2**).

Heat shock factor-1 (HSF-1) is a transcription factor required for the expression of some heat shock proteins, and overexpression of *hsf-1* produces an increase of 40% in life span as compared with wild-type animals. HSF interacts with the insulin signaling pathway such that DAF-16 is required for HSF-associated life span extension. Under stress conditions, DAF-16 proteins relocalize from the cytoplasm to the nucleus, where they possibly activate the transcription of stress response and metabolic genes.

Molecular chaperones are proteins involved in folding newly made proteins and repair the potential damage caused by misfolding under stressful

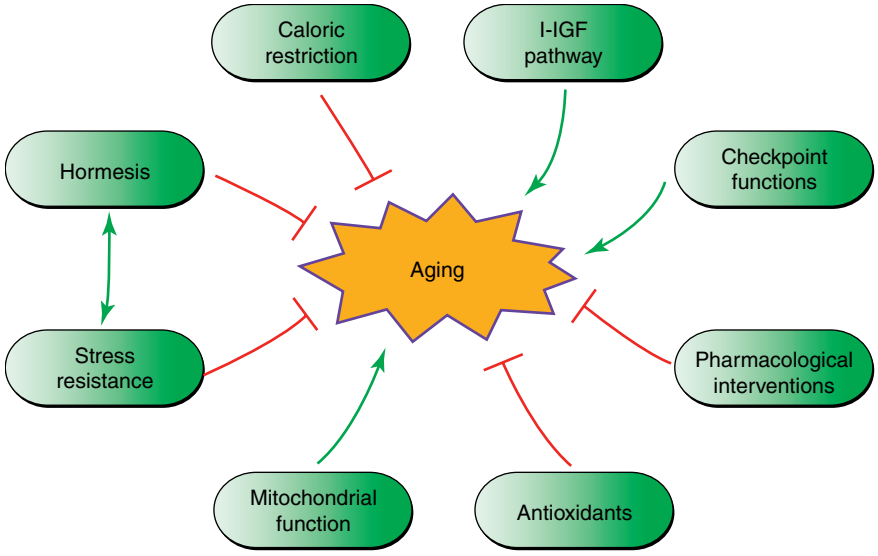

Figure 2 Principal factors that modulate aging. Both genetic and environmental factors determine normal life span. Caloric restriction, hormesis, stress resistance, and antioxidants extend life span, while mitochondrial function, DNA damage cell cycle checkpoint functions, and insulin/IGF-1 signaling shorten life span.

conditions. Gordon J. Lithgow's laboratory proposed and demonstrated that overexpression of molecular chaperones (HSP-16, in this case) was in part responsible for life span extension in insulin-signaling mutants. In addition, HSP-70 levels influence life span of both worms and flies.

There are many examples of connections between stress resistance and longevity in mouse models. For example, the DAF-16 homologue FOXO is regulated by the protein hormone Klotho. Klotho activates FOXO, leading to elevated expression of Mn superoxidase dismutase activity, which in turn leads to oxidative stress resistance. The Klotho overexpressing mouse is also long lived. The long-lived insulin/IGF-1 signaling mouse models are also resistant to oxidative stress suggesting a mechanistic connection.

Hormesis

It has been proposed that if cells and organisms are exposed to brief periods of non-lethal stress, the resulting stress response could produce beneficial effects (**Figure 2**). This phenomenon is known as hormesis. In an aging context, hormesis can be described as the anti-aging and longevity-promoting effects resulting from the cellular response to mild stress. Hormesis has been shown to increase the life span of many different species, including yeast, nematodes, flies, mice, and human cells. Multiple stressors, such as increased heat, high oxygen, and gamma irradiation can induce such a hormetic response in *C. elegans*, and a single pretreatment of heat early in life is sufficient to moderately extend life span. It is clear from this discussion that a simple model organism such as this nematode could be very useful in order to fully understand the molecular mechanisms underlying hormesis.

Interestingly, some beneficial effects of chronic but mild undernutrition have been reported in humans. Peripheral blood lymphocytes from people with low body mass index show high ability of DNA repair and elevated levels of DNA polymerase b that remained during the entire aging process. It has been also reported that sporadic fasting has positive effects on glucose metabolism and neuronal resistance to injury. Two popular lifestyle interventions, exercise and reduced food intake, which could exert their beneficial effects through hormesis, are being recognized as a successful way to achieving a healthy aging.

Caloric Restriction

Throughout history, different cultures have advertised the benefits of food intake limitation. Maybe the first serious scientific work related to restricted diets and their effect in life span was performed by McCay and co-workers in 1935, who fed a diet lacking 20% of total calories and found a significant increase in mean and maximum life span in rodents. A reduction in the total amount of food intake is currently termed caloric restriction (CR), and it has been claimed to be the only effective way to extend life span in mammals without pharmacological or genetic intervention (**Figure 2**). Despite the great interest in CR research during the past years, most of

the theories are not able to explain the complex effects observed in CR experimentation. However, CR has been shown to increase the life span of almost all organisms tested. There are interesting exceptions such as wild mouse strains, mouse populations that have not been subject to lab adaptation, which fail to respond to caloric restriction.

Research performed in yeast and *Drosophila* has targeted the signaling components that respond to different nutritional conditions. Interestingly, the deletion of one of these components, TOR kinase (target of rapamycin), is able to extend life span in *C. elegans*. Life span extension elicited by CR is not fully dependent on the insulin/IGF signaling pathway since it is also observed in worms lacking the forkhead protein DAF-16. However, considerable effort has gone into determining factors important for CR effects in the budding yeast *S. cerevisiae*. Life span is commonly measured as the number of daughter cells produced sequentially during asymmetric cell division. Reduction of glucose in the growth media increases this reproductive life span, and the protein deacetylase SIR2 has been shown to be required for this effect under certain CR conditions. SIR2 overexpression also extends life span in yeast and in *C. elegans*. Whether SIR2-like protein affects mammalian life span and the exact mechanisms of SIR2 action in simple organisms are under intense investigation.

In addition to extending life span, CR could be beneficial for the brain and its function. For example, CR improves the performance of aged rodents on learning, memory, and coordination tasks. In other work, CR improves the function of brain cells in animal models of several neurodegenerative diseases, such as Alzheimer's disease, Parkinson's disease, Huntington's disease, and stroke, suggesting that CR may protect against the effects of age-related brain disease. It has been suggested that CR could produce these protective effect in brain cells by decreasing the amount of destructive free radical molecules.

Finally, assuming that the innate mechanisms that promote health and life span increase during stress, it should be possible to design molecules that can activate them (stress response mimetics). The search for potential CR mimetic molecules has focused on those that could modulate energy metabolism. Two examples include 2-deoxyglucose (2DG) and members of the biguanide class of drugs, which originate from the French lilac (*Galega officinalis*). 2DG is a synthetic glucose analog that inhibits the glycolytic enzyme phosphohexose isomerase. 2DG injected into rodents suppresses tumor growth, decreases insulin and body temperature, and increases glucocorticoids and results in CR. Unfortunately, chronic administration of 2DG has deleterious effects on the heart, making it unlikely to extend life span of the animals in this study. Similar effects occur with metformin, buformin, and phenformin. These findings suggest that mimicking CR in mammals by altering glucose/insulin metabolism may be possible.

Oxidative Stress and Aging

The Mitochondria and the Oxygen Radical Theory of Aging

Mitochondria are the power houses of the cell. These essential double-membraned organelles are vital for energy generation via oxidative phosphorylation, also known as aerobic respiration. The electron transport chain (ETC) is located in the inner mitochondrial membrane. The ETC consists of a series of redox reactions catalyzed by various protein complexes that transfer electrons from reducing equivalents (NADH or $FADH_2$) generated by glycolysis and Kreb's cycle to the final electron acceptor: molecular oxygen. During the translocation of the electrons across the ETC, protons are pumped through the inner mitochondrial membrane. Thus, the mitochondrial matrix is more negatively charged than the cytoplasm, resulting in an electrochemical gradient or voltage generation across the inner mitochondrial membrane. The electrons are transferred from complex I or complex II to III and finally IV. The fourth complex (cytochrome *c* oxidase) transfers electrons to molecular oxygen. The F_1/F_0 ATP synthase (or complex V) permits protons to re-enter the mitochondrial matrix down the established proton gradient. The energy released in this voltage flux is captured by the ATP synthase to phosphorylate ADP to ATP (**Figure 3**).

In 1956, Denham Herman proposed the free radical theory of aging, which postulates that metabolic activities involving oxygen create toxic reactive oxygen species (ROS) that damage cells. At the organismal level the effect is aging. Since 1972 mitochondria have been recognized as a major origin of O_2 radical generation in the cell. ROS include superoxide, peroxide, hydroxyl radical, and several nitrogenous species. ROS causes modifications and denaturation of proteins and lipids. ROS also modifies mitochondrial DNA bases, leading to mutations in genes and hence proteins of the ETC complexes and impairment of ETC efficiency. Aberrant ETC function can lead to increased ROS production and further damage to mitochondrial constituents, including the ETC. A total of 0.4–4% of the molecular oxygen is only partly reduced by the ETC, resulting in superoxide radical ($O_2^{\bullet -}$) production. $O_2^{\bullet -}$ is produced during the two-cycle reoxidation or reduction of

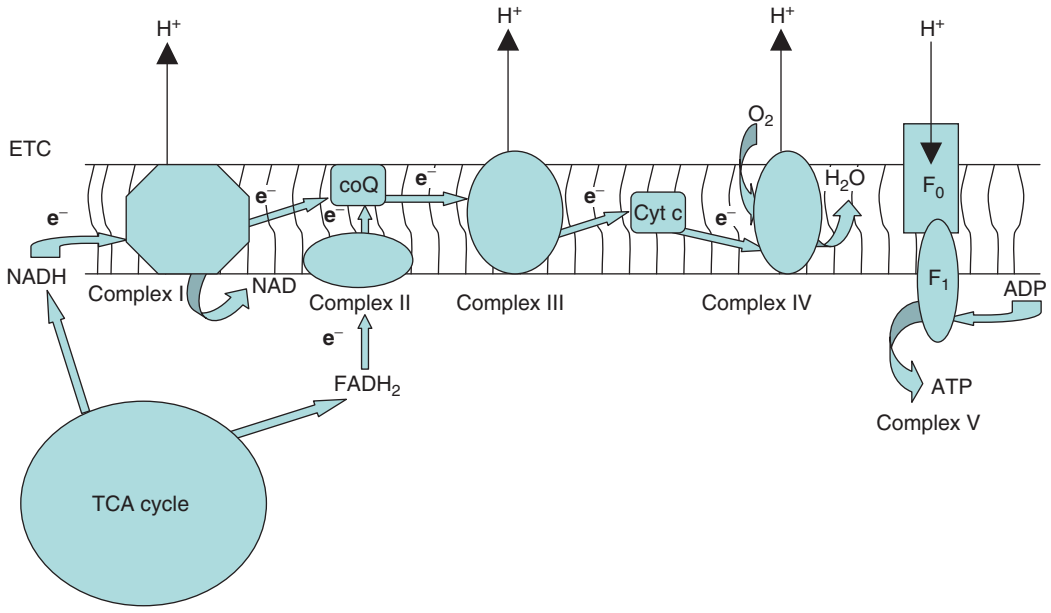

Figure 3 Schematic representation of the mitochondrial electron transport chain located in the inner mitochondrial membrane. The electrons are donated by reducing equivalents generated by the tricarboxylic acid (TCA) cycle, present in the mitochondria. The proton gradient forms as protons are pumped to the cytoplasm by the ETC complexes.

ubiquinone. During this process, semiubiquinone, an intermediate highly reactive toward O_2, is formed.

Mitochondria and the ETC itself are subjected to oxidative damage in a variety of metabolic states. This is thought to decrease mitochondrial functions, including ATP generation during aging. Decreasing ROS generation or increasing ROS-neutralizing mechanisms should therefore protect mitochondria and their functions from oxidative damage, thus slowing the aging process. In support of this idea, ROS scavenging enzymes such as catalase and superoxide dismutase (SOD) are elevated in *C. elegans daf-2* mutants (lacking the insulin/IGF-1 receptor) that live longer than wild-type organisms. Further evidence comes from additional *Drosophila* studies and *C. elegans* studies. The glutathione redox system maintains the optimal redox status in the cell and also detoxifies ROS radicals. This activity is dependent largely on the ratio of reduced/oxidized glutathione. The overexpression of the enzyme involved in synthesis of glutathione-gamma-glutamyl cysteine ligase (*gcl*) increases the glutathione pool and longevity in *Drosophila*. In the worm, daily feeding of catalytic antioxidants leads to thermal stress resistance, paraquat resistance, and extended life span.

Mitochondrial Genes Influence Life Span

New insights into mitochondrial function were obtained from independent RNAi-based approaches that targeted the expression of mitochondrial proteins in *C. elegans*. The RNAi screens suggest that when several essential mitochondrial proteins are absent or undetectable, life span is extended. These proteins included ATP synthase, subunits of ETC complexes I, III, and IV, as well as non-ETC mitochondrial proteins such as leucyl tRNA synthetase and two mitochondrial carrier proteins. In fact, $>50\%$ of genes involved in energy metabolism that when suppressed extend life span encode ETC subunits, and most have human orthologs. Mitochondrial ETC inhibitors also had similar life span-increasing effects. Interestingly the knockdown of glycolysis, triacylglycerol synthesis, or tricarboxylic acid (TCA) cycle genes also extends *C. elegans* life span, although there is no O_2 or ROS production in these reactions.

The mechanism of all of these interventions in metabolism is far from clear. Although counterintuitive, a slower ETC does not result in decreased $O_2^{\bullet -}$ production. On the contrary, slowing down the ETC should increase the half-life of ubisemiquinone (the highly O_2 reactive intermediate) and hence increase ROS production in mitochondrial ETC mutants. The O_2 consumption and ATP levels are decreased in these animals. The ETC mutants are highly resistant to H_2O_2 but hypersensitive to paraquat. Perhaps the high endogenous ROS production expected from a sluggish ETC induces upregulation of ROS scavengers such as catalase, with a resultant hormesis. This would explain resistance to H_2O_2. Hypersensitivity

to paraquat is to be expected in the context of the compromised ETC of these mutants. Paraquat interferes directly with the ETC.

Most ETC mutants show extended life span only when the ETC subunits are suppressed during development. Suppression of an ETC component by RNAi during development permanently decreases ATP levels and O_2 consumption throughout the life cycle. Restoring ETC component levels to normal by removing RNAi during postdevelopmental periods does not restore ATP levels or O_2 consumption to normal, and life span remains extended. On the other hand, decreasing expression of ETC subunits by RNAi knockdown in adulthood does not cause life span extension, even though ATP levels and O_2 consumption decrease. These observations show that impairment of mitochondrial respiration during development establishes a regulatory mechanism that extends life span and maintains ATP production and O_2 consumption rates to match those present during development.

This discovery warrants similar studies in vertebrate models. It has been long established that CR alters metabolism and enhances life span. Mitochondrial retrograde signaling is a pathway of communication from mitochondria to the nucleus that influences many cellular and organismal activities. In yeast it senses mitochondrial dysfunction, which initiates readjustments of carbohydrate and nitrogen metabolism. In the worm, the *sir-2* gene product appears to be involved in the sensory pathway. Hence, it is possible that the partially impaired mitochondrial respiration in ETC mutants induces a metabolic environment similar to CR, leading to an increase in life span.

To complicate matters, there are also short-lived ETC mutants that are hypersensitive to oxidative stressors, e.g., *mev-1*, which encodes cytochrome b, the large subunit of complex II, and *gas-1*, which encodes the iron-containing subunit of complex I. The very first mitochondrial mutant to be discovered was *clk-1* in *C. elegans*. *Clk-1* mutant had a prolonged developmental period. The *clk-1* gene encodes an enzyme involved in the synthesis of coenzyme Q (ubiquinone), an electron carrier that is essential for ETC redox reactions. In yeast, worms, and mice, *clk-1* negative mutants do not synthesize ubiquinone but accumulate its precursor, demethoxyubiquinone (DMQ). The yeast mutant is respiration deficient while mutant mouse embryos become non-viable by day 10.5. Similarly, *clk-1* negative worms undergo developmental arrest. However, *clk-1*$^{+/-}$ heterozygous mice express ubiquinone, yet are long lived. Enhanced life span is also seen in worms that acquire ubiquinone when fed on bacteria that produce the coenzyme. Thus, in both mouse and worm it seems that it is not the absence of ubiquinone that confers longevity. The role of mitochondrial function in life span extension remains elusive.

Summary

Both genetic and environmental influences on life span are being discovered. Aging appears to be a consequence of the action of many hundreds of genes but can be slowed significantly by alterations that affect maintenance and metabolic functions (**Figure 2**). Slowed aging postpones disease, prompting the notion that pharmacological agents that slow aging may be useful in the treatment of age-related disease.

See also: Diet and Nutrition; Life Span Theory; Metabolism: Carbohydrate, Lipid and Protein; Stress: Physiological; Theories of Aging: Biological.

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Smell and Taste

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Glossary

Chemical Senses – Senses that detect chemical stimuli and encode chemosensory information into neural signals, e.g., smell and taste.

Olfaction – Sense of smell.

Transduction Mechanism – The biochemical process by which stimuli (in this case, chemicals) stimulate the receptors to induce a signal.

Overview

The loss of smell and taste commonly occurs in elderly persons. It can result from normal aging, certain disease states (especially Alzheimer's disease), medications, surgical interventions, and environmental exposure. This article describes the diagnostic terms used to classify these losses and the extent of the losses at threshold and suprathreshold concentrations in older individuals, along with the anatomical and physiological changes that occur in the smell and taste system with age. The contribution of environmental pollutants, medical conditions, and medications to normal age-related changes is also described.

Classification and Consequences of Smell and Taste Loss

The senses of smell and taste are termed chemical senses because they detect chemical stimuli and encode chemosensory information into neural signals. A variety of diagnostic terms have been used to describe smell and taste disorders. Standard classification terms for olfactory disorders are anosmia (absence of smell), hyposmia (diminished sensitivity of smell), and dysosmia (distortion of normal smell). Phantosmia, a type of dysosmia, refers to perception odor in absence of an odor stimulus, and parosmia refers to distortion of odor perception when an odor is present. For taste, diagnostic terms include ageusia (absence of taste), hypogeusia (diminished sensitivity of taste), and dysgeusia (distortion of normal taste). Dysosmia and dysgeusia are not necessarily correlated with decreased ability to perceive chemosensory stimuli. While disorders of smell and taste can occur throughout the life span, they are far more prevalent in an elderly population. The terms presbyosmia and presbygeusia are occasionally used to describe olfactory or taste losses with age. Typically, olfactory perception is more likely to be

disrupted during the aging process than the sense of taste.

The decrements in smell and taste perception that occur with advancing age can have profound effects on integral activities in the daily lives of elderly persons. These chemical senses provide critical information about potential dangers in the environment. For this reason, smell and taste losses are not merely an inconvenience; rather, they leave elderly persons vulnerable to hazards such as spoiled foods, smoke, hazardous chemicals, natural gas leaks, and dangerous fumes. Smell and taste losses can impair the ability to perform routine activities such as food shopping and meal preparation, personal hygiene, and proper handling of household chemicals such as bleach, cleaning products, and pesticides. Loss of the senses of smell and/or taste can also affect elderly who are still working in professions that are best performed by persons with intact chemosensation, such as gourmet chefs, bakers, beauticians, perfumers, wine specialists, chemists, nurses, gardeners, florists, plumbers, or caregivers of infants or small children in diapers. As chemosensory losses progress, alterations in food selection and intake can exacerbate disease states, produce weight loss, and impair nutritional status and immunity. Conversely, nutritional deficits may induce smell or taste losses. Importantly, deficits in the chemical senses can severely impact quality of life because they reduce pleasure and comfort obtained from food, beverages (such as coffee), flowers, fragrances, and natural settings such as forests.

Qualitative Range of Smell and Taste

The qualitative range for odor is extremely broad; it has been suggested that humans can distinguish up to 10 000 different chemicals. There have been many classification schemes for odors, but most are inadequate to encompass the vast qualitative range. For taste, however, most scientific texts state that are only four basic qualities: sweet, sour, salty, and bitter. This 'four-taste' position ignores extensive experimental data in a variety of species, including humans, showing that taste qualities such as metallic (iron salts), astringent (wines), umami (monosodium glutamate/5′-nucleotides), and chalky (calcium salts) are also mediated by taste nerves. Furthermore, amino acids other than monosodium glutamate often have unique taste qualities that cannot be described by sweet, sour, salty, or bitter. Sensations from fats and fatty acids can be detected on the tongue on the lateral posterior sides without tongue movement, and electrophysicological data have shown that fatty acids activate taste nerves. Although the English language lacks the vocabulary to describe the full range of taste sensations, other languages have more descriptors for tastes. For example, the Japanese word *umami* is used to describe the taste of monosodium glutamate as well as the meaty taste of certain fish and broths.

Losses of Smell and Taste Perception in the Elderly

Smell and taste losses have been associated with normal aging, certain disease states (especially Alzheimer's disease), medication use, surgical interventions, and environmental exposure (see **Tables 1–3**). Information regarding some of these losses comes from clinical reports, while other data derive from experimental studies. Both threshold and suprathreshold methodologies have been used experimentally to quantify smell and taste decrements in the elderly. Threshold tasks determine the lowest concentration at which tastes and odors can first be detected or recognized. Suprathreshold studies include identification and discrimination tasks as well as assessment of perceived intensity.

Impairment at Threshold Concentrations

For both smell and taste, detection and recognition thresholds are elevated in older persons. For odors, elevated detection and recognition thresholds have been measured for a broad range of individual volatile compounds as well as mixtures including food odors. An overview of odor threshold studies suggests that thresholds in a healthy elderly cohort are 2 to 15 times higher than in a young group. The degree of olfactory loss tends to be uniform across compounds, independent of their chemical structures. Olfactory losses at the threshold level typically begin to occur in the sixth decade of life, and odor thresholds continue to increase (less sensitivity) from the sixth to the seventh and eighth decades. While olfactory threshold measures are not strongly affected by cognitive losses, suprathreshold performance can be severely impaired.

For taste, elevated thresholds (i.e., reduced sensitivity) for sweet, sour, salty, and bitter as well as for tastes of amino acids including glutamate salts have been quantified in healthy older individuals. The degree of loss varies according to the chemical structure of the compound tested as well as the medical condition, pharmacological regimen, and environmental exposure history of the individual. Threshold measurements for the four prototypical tastes of sweet, sour, salty, and bitter, using sip-and-spit techniques that stimulate the whole mouth, suggest that

Table 1 Representative compounds, dusts, and processes associated with chemosensory disorders in humans with chronic exposure

Metallurgical compounds and processes
Cadmium compounds including oxides
Chromium, including chromate salts and cromium plating
Lead
Magnet production, including iron, aluminum, nickel, cobalt, and chromium powders
Mercury
Nickel, including nickel hydroxide, nickel plating and refining
Silver plating
Steel production
Zinc, including zinc chromate, zinc production
Dusts
Ashes, incinerator
Cement
Chemicals
Coke
Grain
Hardwoods
Lime
Printing
Silicosis
Non-metallic inorganic compounds
Ammonia
Carbon disulfide
Carbon monoxide
Chlorine
Hydrazine
Fluorides
Hydrogen selenide
Hydrogen sulfide
Nitrogen dioxide (NO_2)
Phosphorous
Sulfur dioxide
Organic compounds
Acetates, butyl and ethyl
Acetone
Acetophenone
Acrylate and methacrylate vapors
Benzene
Benzine
Chloromethanes (CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4)
Formaldehyde
Menthol
Organophosphates and other insecticides
Pentachlorophenol
Petroleum
Solvent mixtures
Trichloroethylene
Manufacturing processes
Acids (organic and inorganic)
Asphalt (oxidized)
Cement works
Cotton, knitting factory
Cutting oils (machining)
Flour, flour mill
Fragrances
Paint
Paper, packing factory
Pavinol, a synthetic leather containing dibutyl phthalate
Peppermint
Spices, including paprika
Tobacco
Varnishes
Waste water

Table 2 Representative medical conditions that alter smell and/or taste

Classification/Condition	*Smell*	*Taste*
Nervous		
Alzheimer's disease	×	×
Bell's palsy		×
Damage to chorda tympani		×
Down's syndrome	×	
Epilepsy	×	
Guillain-Barre syndrome		×
Familial dysautonomia		×
Head trauma	×	×
Korsakoff's syndrome	×	
Migraine	×	
Multiple sclerosis	×	×
Parkinson's disease	×	
Raeder's paratrigeminal syndrome		×
Tumors and lesions	×	×
Nutritional		
Cancer		×
Chronic renal failure	×	×
Liver disease including cirrhosis	×	×
Niacin (vitamin B_3) deficiency		×
Thermal burn		×
Trimethylaminuria	×	
Vitamin B_{12} deficiency	×	
Zinc deficiency		×
Endocrine		
Adrenal cortical insufficiency	×	×
Congenital adrenal hyperplasia		×
Cretinism		×
Cushing's syndrome	×	×
Panhypopituitarism		×
Hypothyroidism	×	×
Diabetes mellitus	×	×
Gonadal dysgenesis (Turner's syndrome)	×	×
Hypogonadotropic hypogonadism (Kallman's syndrome)	×	
Pseudohypoparathyroidism	×	×
Local		
Adenoid hypertrophy	×	
Allergic rhinitis, atopy, and bronchial asthma	×	
Crouzon's syndrome	×	
Facial hypoplasia	×	×
Glossitis and other oral disorders		×
Leprosy	×	×
Oral Crohn's disease		×
Radiation therapy		×
Sinusitis and polyposis	×	
Sjögren's syndrome	×	×
Viral and infectious		
Acute viral hepatitis	×	
Influenza-like infections	×	×
Other		
Amyloidosis and sarcoidosis	×	×
Cystic fibrosis	×	×
High altitude		×
Hypertension		×
Laryngectomy	×	×
Major depressive disorder	×	×

Table 3 Representative medications that have been clinically reported to alter the chemical senses

Amebicides, antifungals, and anthelmintics
Metronidazole
Niclosamide
Niridazole
Terbinafine
Anesthetics
Benzocaine
Dibucaine hydrochloride
Euprocin
Lidocaine
Procaine hydrochloride
Propofol
Tropacocaine
Anticholesteremic and antilipidemics
Atorvastatin calcium
Cholestyramine
Clofibrate
Fluvastatin sodium
Gemfibrozil
Lovastatin
Pravastatin sodium
Probucol
Simvastatin
Anticoagulants
Phenindione
Warfarin sodium
Antihistamines
Chlorpheniramine maleate
Loratadine
Terfenadine and pseudoephedrine
Antimicrobial agents
Amphotericin B
Ampicillin
Atovaquone
Azithromycin
Aztreonam
Bleomycin
Carbenicillin indanyl sodium
Cefamandole
Cefpodoxime proxetil
Ceftriaxone sodium
Cefuroxime axetil
Cinoxacin
Ciprofloxacin
Clarithromycin
Clindamycin phosphate
Clofazimine
Dapsone
Enoxacin
Ethambutol hydrochloride
Griseofulvin
Imipenem-cilastatin sodium
Lincomycin HCl
Lomefloxacin HCl
Mezlocillin sodium
Norfloxacin
Ofloxacin
Pentamidine isethionate
Piperacillin and tazobactam sodium
Pyrimethamine
Rifabutin
Sulfamethoxazole
Tetracycline

Table 3 (*Continued*)

Ticarcillin disodium and clavulanate potassium
Tyrothricin
Antiproliferative, including immunosuppressive agents
Azathioprine
Carmustine
Cisplatin
Carboplatin
Cyclosporine
Doxorubicin and methotrexate
Fluorouracil
Interferon
Vincristine sulfate
Antirheumatic, antiarthritic, analgesic-antipyretic, and anti-inflammatory
Auranofin
Aurothioglucose
Benoxaprofen
Butorphanol tartrate
Choline magnesium trisalicylate
Colchicine
Dexamethasone
Diclofenac potassium/diclofenac sodium
Dimethyl sulfoxide
Etodolac
Fenoprofen calcium
Flurbiprofen
Gold
Hydrocortisone
Hydromorphone HCl
Ibuprofen
Ketoprofen
Ketorolac trometh-amine
Morphine sulfate
Nabumetone
Nalbuphine HCl
Oxycodone HCl
Oxaprozin
D-penicillamine and penicillamine
Pentazocine HCl
Phenylbutazone
Piroxicam
Salicylates
Sulindac
Sumatriptan succinate
5thiopyridoxine
Antiseptics
Hexetidine
Antispasmodics, irritable bowel syndrome
Dicylomine HCl
Oxybutynin chloride
Antithyroid agents
Carbimazole
Methimazole
Methylthiouracil
Propylthiouracil
Thiouracil
Anti-ulcerative
Clidinium bromide
Famotidine
Glycopyrrolate
Hyoscyamine sulfate
Mesalamine
Misoprostol
Omeprazole

Table 3 (*Continued*)

Propantheline bromide
Sulfasalazine
Antiviral
Acyclovir
Foscarnet sodium
Idoxuridine
Interferon α-n3
Interferon β-1b
Rimantadine HCl
Agents for dental hygiene
Sodium fluoride
Sodium lauryl sulfate
Chlorhexidine digluconate mouthrinses
Bronchodilators and anti-asthmatic drugs
Albuterol sulfate
Beclomethasone dipropionate
Bitolterol mesylate
Cromolyn sodium
Flunisolide
Metaproterenol sulfate
Nedocromil
Pirbuterol acetate inhalation aerosol
Terbutaline sulfate
Cardiovascular drugs including antihypertensives
Acetazolamide
Adenosine
Amiodarone HCl
Amiloride and its analogs
Amlodipine besylate
Benazepril HCl
Bepridil
Betaxolol HCl
Bisoprolol fumarate
Captopril
Clonidine
Diazoxide
Diltiazem
Doxazosin mesylate
Enalapril
Esmolol HCl
Ethacrynic acid
Flecainide acetate
Fosinopril sodium
Guanfacine HC
Hydrochlorothiazide
Labetalol HCl
Metolazone
Mexiletine HCl
Moricizine HCl
Nifedipine
Procainamide HCl
Propafenone HCl
Propranolol HCl
Ramipril
Spironolactone
Tocainide HCl
Triamterene/hydro-chlorothiazide
HIV-related therapeutic drugs
Didanosine
Indinavir
Lamivudine
Nevirapine
Saquinavir
Stavudine

Table 3 (*Continued*)

Zalcitabine
Hyper- and hypoglycemic drugs
Diazoxide
Glipizide
Phenformin and derivatives
Hypnotics and sedatives
Estazolam
Flurazepam HCl
Midazolam HCl
Prochlorperazine
Promethazine HCl
Quazepam
Triazolam
Zolpidem tartrate
Zoplicone
Muscle relaxants and drugs for treatment of Parkinson's disease
Baclofen
Chlormezanone
Cyclobenzaprine HCl
Dantrolene sodium
Levodopa
Methocarbamol
Pergolide mesylate
Selegiline HCl
Psychopharmacologics including antiepileptics
Alprazolam
Amitriptyline HCl
Amoxapine
Buspirone HCl
Carbamazepine
Clomipramine HCl
Clozapine
Desipramine HCl
Doxepin HCl
Felbamate
Fluoxetine HCl
Imipramine HCl
Lithium carbonate
Maprotiline HCl
Nortriptyline HCl
Paroxetine HCl
Phenytoin
Pimozide
Protriptyline HCl
Psilocybin
Risperidone
Sertraline HCl
Trazodone HCl
Trifluoperazine HCl
Trimipramine maleate
Venlafaxine HCl
Sympathomimetic drugs
Amfetamine
Benzphetamine HCl
Dextroamphetamine sulfate
Fenfluramine HCl
Mazindol
Methamphetamine HCl
Phendimetrazine tartrate
Phentermine
Vasodilators
Bamifylline HCl
Dipyridamole

(*Continued*)

Table 3 (*Continued*)

Isosorbide mononitrate
Nitroglycerin patch
Oxyfedrine
Others (indication)
Allopurinol (reduces serum and urinary uric acid)
Antihemophilic factor (recombinant) (clotting factor hemophilia)
Antithrombin III (human) (antithrombin III deficiency)
Calcitonin (Paget's disease, hypercalcemia, osteoporosis)
Etidronate (hypercalcemia, antipsoriatic)
Etretinate (antipsoriatic)
Gadodiamide (diagnostic imaging product)
Germine monoacetate (Eaton-Lambert syndrome)
Granisetron HCl (antiemetic/antinauseant)
Histamine phosphate (control for allergic skin testing)
Histratrol (95)
Iohexol (diagnostic imaging product)
Iron sorbitex (hematinic)
Leuprolide acetate (inhibits gonadotropin secretion/prostatic cancer)
Levamisole HCl (immunomodulator; restores depressed immune function)
Mesna (detoxifying agent)
Methylergonovine maleate (prevents postpartum hemorrhage)
Pentoxifylline (blood viscosity modulator)
Potassium iodide (expectorant)
Succimer (lead poisoning)
Ursodiol (gall stone dissolution)
Vitamin D/calcitriol (hypocalcemia)
Vitamin K_1/phytonadione (coagulation disorders)

Adapted from Schiffman SS and Zervakis J (2002) Taste and smell perception in the elderly: effect of medications and disease. *Advances in Food and Nutrition Research* 44: 247–346.

threshold losses are small in elderly who suffer from no diseases and take no medications. Measurable taste losses in non-medicated elderly are often greater, however, for non-prototypical tastes such as salts of calcium, magnesium, and potassium with a variety of anion types. Regional losses in taste sensitivity can also occur over different areas of the tongue for a given individual.

The greatest losses in taste sensitivity at threshold levels are generally found in elderly individuals who take medications. For elderly community-dwelling individuals with one or more medical conditions and taking an average of 3.4 medications, mean 'whole mouth' taste thresholds (using sip-and-spit techniques) have been reported to be 11.6 times higher for sodium salts, 4.3 times higher for acids, 7.0 times higher for bitter compounds, 2.5 times higher for amino acids, 5.0 times higher for glutamate salts, and 2.7 times higher for sweeteners compared with thresholds for a young cohort. For the most part, detection (though not necessarily recognition) thresholds can be found using sip-and-spit methods for most elderly with a broad range of illnesses, which suggests that total absence of taste (ageusia) is relatively rare.

Impairment of Suprathreshold Perception

Impairment of suprathreshold odor perception in the elderly is more pronounced than for taste. Some but not all data suggest that women experience fewer losses than men. Compared to their younger counterparts, the elderly have a reduced capacity to discriminate among odors of different qualities and to identify odors. While performance on tasks that require identification of odors is impaired in many healthy elderly persons, there is heterogeneity among individuals. A population-based cross-sectional study in the United States found that the prevalence of impaired ability to identify odor increases from 17.3% for persons 60 to 69 years of age to 29.2% for persons 70–79, and to 62.5% for 80- to 97-year-olds. Based on these prevalence figures and on United Nations projections of global population growth, the number of individuals projected to have olfactory impairments worldwide by 2050 is at least 230 million. For most persons, the loss in the ability to identify odors occurs gradually over the years, and some older individuals are not aware of the problem until it becomes very troubling. Odor identification is especially impaired in patients with certain neurodegenerative diseases, including Alzheimer's and Parkinson's disease.

Age-related impairments of suprathreshold odors also interfere with the perception of complex food systems, which requires integration of smell and taste sensations. Elderly individuals with olfactory impairment often attribute reduced intensity of foods and beverages to losses in their 'taste' perception. The reason for this incorrect attribution is that they presume that sensations of food in the mouth are tastes; however, they are largely produced by odors. When food is taken into the oral cavity, volatile odorous molecules travel up the back of the throat, and food odors are perceived retronasally. Reduced intensity of odors perceived retronasally interferes with the ability to identify foods. Malnutrition and wasting further exacerbate the ability to identify foods and food ingredients based on sensory cues.

The majority of suprathreshold studies suggest that, compared to a young cohort, elderly persons perceive tastes as being less intense. Any differences in various reports regarding the degree of suprathreshold taste loss probably arise in part from the medical status and pharmaceutical agents used by the subjects, their environmental exposure histories, and their cognitive status. Reductions in perceived suprathreshold taste intensity for sweeteners and amino acids using whole mouth sip-and-spit testing indicate that the degree of loss is dependent upon the chemical structure of the tastant. The ability to

discriminate intensity differences between various concentrations of a tastant is also impaired with age. The prevalence of taste disorders is not yet known, although clinical complaints suggest they are less common than olfactory disorders. Although taste losses may occur less frequently than smell losses, when they do occur, they are more complicated because they can be quality specific or localized to certain areas of the tongue.

Suprathreshold taste losses for sweet and salty qualities can have health consequences for the elderly. For example, if persons with diabetes add more sugar to their foods due to reduced intensity, this could have an adverse effect on their blood sugar. If persons with hypertension add more NaCl to their foods because of reduced salty sensations, this can make it difficult for them to comply with salt-restricted diets. Furthermore, if salt-sensitive hypertensive elderly patients add NaCl to reduce bitterness of foods (NaCl can reduce bitterness), this can elevate blood pressure.

Anatomy and Physiology of Smell and Taste

While both smell and taste sensations are activated when molecules bind to receptors on chemosensory cells, the peripheral anatomy and central neural pathways for the two senses are distinct.

Smell

Olfactory receptor neurons (ORNs) are bipolar neurons that are activated when airborne molecules in inspired air bind to olfactory receptors (ORs) expressed on their cilia. The ORs belong to a G-protein-coupled receptor superfamily. The ORNs are located high within the nasal vault in the olfactory epithelium. The olfactory epithelium is situated on the undersurface of the cribriform plate of the ethmoid bone, on the medial surface of the superior and middle turbinates, and on the upper nasal septum. The turbinates are scrolled spongy bones in the nasal passages that create airflow patterns that allow volatile compounds inhaled through the nares to reach the olfactory epithelium. ORs in the olfactory epithelium can also be activated through 'retronasal olfaction' when molecules from the oral cavity (e.g., from food) pass up through the nasopharynx into the nose.

The axons of the bipolar ORNs pass through small foramina (natural openings) in the cribriform plate joined together in fascicles (bundles), where they synapse in intricate neural masses called glomeruli in the olfactory bulb. Each ORN axon innervates only a single glomerulus. There is considerable convergence at the level of the olfactory bulb, with millions of ORNs converging on far fewer glomeruli. During the aging process, the glomeruli atrophy as fibers degenerate and disappear such that the olfactory bulb takes on a moth-eaten appearance. ORNs are vulnerable to trauma (e.g., blows to head, domestic falls, automobile accidents, and assaults) due to shearing of the axons by the ethmoid bone.

Axons from two principal cell types (mitral and tufted cells) emerge from the olfactory bulb to form the lateral olfactory tract, which subsequently projects to the anterior olfactory nucleus, the olfactory tubercle, the prepyriform cortex, and the amygdala, which are known collectively as the olfactory cortex. Many of these structures constitute the so-called 'limbic system' of the brain, which also processes emotions and memories. The neuroanatomical overlap between neurons that mediate olfaction and emotions provides an anatomical basis for the capacity of odors to produce hedonic responses. Olfactory information is ultimately transmitted to the hypothalamus, an area of the brain that is intricately involved in eating and nutrition.

The direct accessibility of ORNs to airborne agents makes them vulnerable to toxins and infectious agents that occur in breathed air. This vulnerability to the damage from the external environments is probably why ORNs, unlike most other neurons, have the ability to regenerate from a precursor population. ORNs turn over every 30 days on average; they are replaced from a stem cell population of basal cells.

Taste

Taste sensations occur when chemicals come in contact with taste receptor cells that are clustered into taste buds located primarily in structures called papilla on the tongue and on the surfaces of the epithelium of the soft palate, pharynx, larynx, epiglottis, uvula, and the first third of the esophagus. Three types of papilla located on the tongue contain taste buds. Papillae distributed on the anterior two-thirds of the dorsal tongue are called fungiform papillae and generally contain 1–18 taste buds. Foliate papillae are located on the posterior lateral sides of the tongue in vertical folds and contain taste receptor cells that are especially sensitive to sour tastes. Circumvallate papillae are located on the back of the tongue and are arranged in a chevron-shaped form pointing caudally; they are called circumvallate papillae because they are surrounded by 'moats.' Taste buds are composed of 50–100 neuroepithelial cells with apical microvilli that contain receptors in

their membranes. The microvilli project through a central pore in the taste bud to contact chemical stimuli. Chemicals from food stimulate receptors on the microvilli during chewing and swallowing. Tongue movements, such as pressing food (e.g., chocolate candy) against the roof of the mouth, improve and prolong taste sensations on the soft palate. Taste input from the soft palate is impaired in elderly persons who wear dentures that cover the roof of the mouth. Taste receptor cells in the buds have a limited life span and continually regenerate with a turnover time of approximately 10 to 10.5 days. The taste receptor cells are replaced from basal cells, which are proliferative cells that are contained in the buds. This constant replacement of taste receptor cells makes the elderly vulnerable to medical treatments and conditions that impair regeneration such as chemotherapy, radiation therapy, and malnutrition.

A variety of membrane components and second messenger systems in taste cells has been shown to play a role in transduction of taste signals, including sodium channels, potassium channels, and two second messenger systems, the adenylate cyclase system, and the phosphatidylinositol system. However, little is known about how they change during the aging process.

Signals from the tongue and throat transmit taste signals via three cranial nerves (VII, IX, and X) from taste receptor cells to the medulla in the brain stem. Taste buds on fungiform papillae and the anterior walls of the foliate papillae are innervated by the chorda tympani nerve, a branch of the seventh cranial nerve. The majority of the taste buds on the soft palate are innervated by another branch of the seventh cranial nerve called the greater superficial petrosal nerve. The remaining taste buds on the soft palate are innervated by the deep petrosal branch of the ninth cranial nerve. Taste buds on the posterior walls of the foliate papillae, the circumvallate papillae, the pharyngeal part of the tongue, and the oral part of the pharynx are innervated by the ninth (glossopharyngeal) nerve. The superior laryngeal branch of the tenth (vagus) nerve innervates taste buds on the far posterior tongue, the epiglottis, the larynx, and the esophagus. The temporal sequence of stimulation of these nerves during oral manipulation and swallowing of food provides the unique 'melody' of each recipe.

The seventh, ninth, and tenth cranial nerves project to the rostral portion of the nucleus of the solitary tract (NST). The NST is a longitudinally organized column of neurons located in the dorsal medulla; it receives visceral sensory information in the caudal portion originating in the esophagus, stomach, intestines, and liver in addition to gustatory information in the rostral portion. Thus, the NST is the first processing area in which taste signals can have an impact on digestion by inducing gastric secretion, increased pancreatic exocrine secretion, and increased secretion of insulin. For this reason, taste losses can have an impact on a range of digestive processes. Axons from the rostral (gustatory) NST project to the ventroposteromedial nucleus of the thalamus, which then projects to the primary gustatory cortex, which consists of two discontinuous areas: the insula-operculum as well as a spatially separate area on the lateral convexity. Neurons on the anterior insula project to taste secondary cortex located on the orbitofrontal surface.

Common Chemical Sense

Another nerve, the trigeminal nerve, is also involved in the perception of chemicals through the so-called 'common chemical sense' or 'chemesthesis.' The ophthalmic branch and maxillary branches of the trigeminal nerve detect irritancy and pungency in the nasal cavity, which can induce sneezing and breath holding when a noxious odor is inhaled. The inhalation of noxious chemicals also results in release of substance P and calcitonin gene-related peptide, producing nasal mucosal edema and secretion. There are central interconnections in the thalamus between trigeminal and olfactory input.

The mandibular branch of the trigeminal nerve mediates pungency and irritation on the anterior two-thirds of the tongue. Examples of chemesthetic qualities are those from nicotine, capsaicin, and piperine (the chemicals in red and black peppers, respectively). Pungency in the nasal and oral cavities is not considered odor or taste but rather a different sense related to nociception.

Causes of Smell and Taste Losses in Older Individuals

There are a multitude of causes of chemosensory alterations in older persons, including anatomical and physiological changes that accompany normal aging, certain disease states (especially Alzheimer's disease), medications, surgical interventions, and environmental exposure.

Anatomical and Physiological Changes in Normal Aging

Many age-related changes in the anatomy and physiology of the olfactory system occur during the aging process; however, analogous changes in the taste system are more equivocal. In the olfactory system, changes occur in the olfactory epithelium,

olfactory bulb and nerves, hippocampus and amygdaloid complex, and hypothalamus, including reductions in cell number, damage to cells, and diminished levels of neurotransmitters. There is an increase in ORN apoptosis (programmed cell death), a decrease in the rate of basal cell proliferation, decreased thickness of the olfactory epithelium, a decreased number of cilia and supporting microvilli, and increased accumulation of electron-dense granules in supporting cells. As the process of olfactory neurogenesis of ORNs begins to degenerate with increasing age, olfactory epithelium is gradually replaced by non-olfactory epithelium, with a subsequent loss in receptor area. This regeneration is inadequate in some cases to replace fragile ORNs damaged by injury (from shear or viral infections) because regenerating olfactory axons are unable to traverse scar tissue and disrupted foramina to reach the olfactory bulb. Regenerating neurons subsequent to injury can also make aberrant synaptic connections, which leads to dysosmia. The olfactory bulb takes on a moth-eaten appearance as glomeruli atrophy and fibers degenerate and disappear. Furthermore, there can be damage to the structures of the limbic system in normal aging, which is exacerbated in Alzheimer's disease.

Studies of anatomical losses in the structures of the taste system in older individuals have drawn conflicting conclusions. Whereas some studies reported reduced numbers of papillae and/or taste buds, other studies found no changes during normal aging. Spatial or regional taste losses have been reported in older individuals, but little is known about why patches of taste buds disappear. It is possible that some physiological taste losses from normal aging occur at taste cell membranes (e.g., altered functioning of ion channels and receptors) rather than from losses of taste buds.

The greater prevalence of generalized olfactory loss compared with generalized taste loss in the elderly can be explained in part by the difference in their relative vulnerabilities to anatomical and physiological damage. As described previously, axons from the olfactory nerve must traverse the cribriform plate of the ethmoid bone before they reach the olfactory bulb. Thus, axons of the olfactory nerve are vulnerable to severing in any type of blow to the head. Olfactory receptors are exposed to the external environment so they can be affected by inhaled environmental toxins. In addition, olfactory receptor cells are located in a compact area, while taste receptors are spread diffusely throughout the mouth and throat. The dispersion of taste receptors relative to smell receptors probably allows some taste receptors to survive a toxicological challenge.

Medical Conditions and Environmental Exposures

Smell and taste losses from normal aging are exacerbated by a wide range of environmental exposures (see **Table 1**) and medical conditions (see **Table 2**). Age-related olfactory losses can be compounded by conductive losses in which there is obstruction of nasal airflow to the olfactory epithelium, e.g., as in chronic rhinosinusitis, polyps, tumors, or allergic rhinitis. Sensory/neural losses secondary to damage to ORNs, the bulb, or central projection areas resulting from upper respiratory infections, head trauma, and toxins (including acute or chronic exposure) can also exacerbate age-related losses. Neural losses in the bulb and at higher cortical levels can occur because ORNs serve as a direct conduit for environmental substances such as metals or viruses to be transported from the nasal cavity to the brain. Extensive scarring along with replacement of olfactory epithelium by respiratory epithelium that occurs subsequent to postviral olfactory loss exacerbates the gradual reduction in olfactory receptor area that occurs during the normal aging process.

In certain disease states prevalent in an older population, such as Alzheimer's disease (AD) and Parkinson's disease, the olfactory losses can be profound. Measures of olfactory ability can be useful in confirming a diagnosis of AD or in identifying those at risk of AD when used in conjunction with other standard diagnostic tools (such as brain imaging). Meta-analyses of studies on olfactory perception in persons with AD conclude that severe losses can occur in five olfactory domains: threshold detection, recognition, discrimination, identification, and olfactory memory. Losses in the ability to remember, recognize, discriminate, and identify odorants occur in the earliest phases of AD, while losses in sensitivity at the threshold level tend to emerge or become more noticeable later as the disease progresses. The gustatory system is not nearly as vulnerable to the ravages of AD as the sense of smell. This relatively greater loss in smell perception in AD compared to taste is due to the neuroanatomical and neurochemical changes in the olfactory system that are characteristic of AD. Neural degeneration in AD occurs in the olfactory bulb, anterior olfactory nucleus, olfactory tubercle, amygdala, prepiriform cortex, hippocampus, entorhinal cortex, uncus, and subiculum. Histopathological changes also occur in the olfactory epithelium. Olfactory measures are also impaired in persons at risk for AD based on documented multigenerational evidence of the disease. Numerous studies have found that at-risk individuals have impaired smell detection and smell memory scores when compared to age-matched controls.

Age-related taste disorders are frequently associated with a range of medical conditions, including infections in the oral cavity and hypopharyngeal mucosa (viral, bacterial, fungal, and parasitic) along with radiation, chemotherapy, and poor oral hygiene (see **Table 2**). Damage to the chorda tympani nerve subsequent to infections (e.g., Lyme disease, chronic otitis media, Bell's palsy) or surgery (dental or ear surgery) can also exacerbate any age-related taste loss that exists. Some studies suggest that elevated salivary copper levels and reduced salivary zinc and manganese levels occur in patients with taste disorders along with decreased salivary concentrations of a matrix metalloproteinase, MMP-3, which is a zinc-containing enzyme that degrades components of the extracellular matrix. Ageusia or severe generalized hypogeusia across all qualities and gustatory neural fields from medical conditions or toxic exposures is relatively rare. However, specific precipitating factors have been linked to taste losses by patients with ageusia or severe generalized hypogeusia, including upper respiratory tract infections, oleoresin capsicum (pepper gas spray) exposure, pesticide exposure, surgery such as tonsillectomy, and head and facial trauma. The prognosis for severe generalized taste loss is poor, and the majority of patients do not regain their sensitivity.

Medications

Medications can also play a major role in smell and taste losses and distortions in older persons, and their role in chemosensory losses is probably underestimated. According to the *Physicians' Desk Reference* (PDR), hundreds of medications (see **Table 3**) have been associated clinically with chemosensory side effects such as 'loss of taste,' 'altered taste,' 'metallic taste,' and many other alterations of smell and taste sensations. Most major drug classes have been implicated in chemosensory disturbances. However, because quantitative chemosensory assessments of large populations taking specific medications have not been performed, it is not known whether these clinically reported losses are indeed gustatory or olfactory in nature, or if they are caused by medications or the medical conditions the medications are designed to treat. According to the PDR, adverse chemosensory side effects from medications usually occur in a minority of patients, but the actual prevalence of medication-induced losses awaits determination by experimental testing procedures. Prescription medications are consumed disproportionately more frequently by the elderly, with per capita usage three times higher than in their younger counterparts. Community-dwelling elderly over the age of 65 typically use 2.9 to 3.7 medications daily, and this number at least doubles for elderly living in retirement and nursing homes.

Little is known about the site or mechanism of action by which most pharmaceutical compounds induce chemosensory losses, but drugs can interfere with smell and taste systems at several levels, including peripheral receptors (e.g., by blocking sodium or calcium channels), chemosensory neural pathways (e.g., by interfering with propagation of signals), and/or the brain (e.g., by diffusing into the brain or brainstem). Quality-specific losses (e.g., specific elevations in taste threshold for salt) may be due to medications that selectively interfere with sodium channels. Drugs secreted into the saliva in the oral cavity can also exert adverse effects on taste perception either by modifying taste transduction mechanisms or by producing a taste of their own. Drugs dissolved in blood can also diffuse from the circulatory system to activate receptors on the basolateral side of taste receptor cells. Some drugs such as chemotherapeutic agents and some antibiotics can interfere with cell turnover of smell and taste receptors (e.g., by blocking mitosis). Steroids can promote overgrowth of *Candida albicans* in the oral cavity, causing a medical condition that interferes with taste.

Brain imaging studies of drug uptake suggest that drug penetration into smell or taste projection areas of the brain or brain stem may account for some alterations in the chemical senses. When a drug is absorbed or injected into the bloodstream, it can pass into the extravascular interstitial space of most tissues (except the brain) through fenestrations in the capillary endothelium. The rate, extent, and pattern of distribution into the interstitial, cellular, and transcellular fluids depend upon the physicochemical properties of the drug. Lipid-soluble drugs that are readily distributed throughout the body including the brain and brain stem could interfere with taste signals by permeating into taste pathways. It is noteworthy that some highly lipophilic and keratophilic drugs such as the allylamine antifungal agent terbinafine are implicated in taste disorders. The brain (and brain stem), however, does have a protective barrier called the blood–brain barrier that restricts the passage of many drugs (especially lipid-insoluble ones) from the blood to the brain. Only small regions of the brain and brain stem, called the circumventricular organs, such as the area postrema (in the medulla), lack a blood–brain barrier. Thus, lipid-insoluble drugs can potentially slip into the brain or brain stem through circumventricular organs and damage taste or smell neurons located in close proximity. For example, drugs could percolate from the area postrema (which lacks a blood–brain barrier) to

neighboring taste neurons in the nucleus of the solitary tract. Inflammatory conditions, neurodegenerative diseases, and advancing age are known to disrupt the blood–brain barrier and predispose an individual to drug-induced chemosensory disorders.

Potential Treatments

There are no standard treatments for smell or taste losses that occur in elderly individuals. However, smell and taste losses from some medical conditions or medications may be reversed upon return to good health and substitution of medications without chemosensory side effects. Amplification of the flavor of foods with simulated flavors (such as commercial cheese, bacon, or butter flavors) can be helpful for persons with hyposmia. A variety of therapeutic options may be available in the future to treat taste or olfactory losses and restore functioning, including antiapoptotic drugs, stem cell treatments, and use of growth factors that promote neuronal regeneration.

See also: Brain and Central Nervous System; Dementia: Alzheimer's; Immune System; Pharmacology.

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Social Cognition

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Glossary

Collaborative Cognition – Engaging in joint problem solving or decision making.

Ego Integrity – A sense of accomplishment with regard to the past and the end of life.

Generativity – Concern for and commitment to future generations.

Morality – The judgment of behaviors and relationships with others.

Social Cognition – Thoughts about others and thoughts about the self in relationship to others.

Sociocultural Perspective – A way of understanding human development that emphasizes the role of the social context in promoting or impeding growth.

Socioemotional Selectivity – The selection of emotionally gratifying social encounters or partners as a result of awareness of the foreshortening of one's life span.

What Is Social Cognition?

Social cognitions involve thoughts about others and thoughts about the self in relationship to others. When we consider cognitive aging from this point of view, it leads us away from traditional research methods and theoretical perspectives that have focused on basic information processing and how it is tied to physiological decline. This body of research has been largely experimental and often has taken place in situations designed to remove the effects of the social context. In contrast, research on social cognition and aging typically is designed to consider how social context affects the thinking of adults.

Work on social cognition has raised important issues inherent in understanding what it means to grow old as a social being. Our life stories, experiences, social competence, core values, and general understanding of the social world have a profound effect on our development at any age. To address these issues, we must consider both basic cognitive processes and abilities in the aging adult as well as everyday cognitive functioning in a social context. Cognitive capacity and speed of processing do show losses in old age. Nevertheless, the vast majority of older adults are skilled and effective in their interactions with their social environment. The basic goal of the social cognitive approach is to understand how people make sense of themselves, others, and events in everyday life. This article examines our current understanding of these processes by looking at five different areas of social cognitive research: person perception and stereotypes, socioemotional selectivity, collaborative cognition, morality, and positive psychology.

Person Perception and Stereotypes

The way that we perceive and understand other people is partly determined by our prior understanding of their group memberships or characteristics. Use of this organized prior knowledge, or stereotype, can result in both negative and positive evaluations of others. As a group, old people are the subject of a great deal of negative stereotyping. They are considered to be frail, forgetful, uninterested in sex, and grouchy. On the other hand, they are also the recipients of some positive stereotyping that attributes greater wisdom, generosity, and social responsibility to them than to younger adults. Even if some of these beliefs may hold a kernel of truth, they are not accurate for all, or even most, older adults.

Researchers have considered the effect of this stereotyping and have found that it can impair the functioning of older adults. The communication predicament model provides one model of the processes that lead to this outcome. In a first encounter with an older person, characteristics that indicate age, for example, wrinkled skin, a quavering voice, or evidence of some mild memory impairment, may be noticed by another social actor. This awareness then triggers a stereotyped expectation of cognitive impairment that leads to altered or simplified speech, for example, calling an older woman 'dear' or addressing her in the second person plural ("How are we today?"). In a vulnerable older person, this response can reinforce stereotyped behaviors that he or she may have already been displaying (e.g., dependence on others, social isolation), further constraining opportunities for normal discourse and resulting in more isolation and feelings of powerlessness. Ultimately, these age-appropriate behaviors can confirm a negative stereotype of aging and negatively influence any new encounter, thus maintaining the negative feedback loop. Research has shown that even in healthy, well-functioning older adults, the activation of a negative stereotype regarding memory functioning is sufficient to create performance deficits on memory tasks. Stereotype threat can have powerful effects on vulnerable individuals.

Age-related stereotyping does not always have a negative effect on behavior, however. There is also evidence that exposure to positive stereotypes can enhance the performance of older adults. Social expectations of leadership, wisdom, or kinkeeping have been shown to result in altered performance, even on tests that do not appear directly related to those characteristics, for example, memory. Positive stereotypes of aging provide a kind of lift to the performance of older adults.

As well as being the recipients of stereotyping, older adults may also be more susceptible to applying stereotypes to others. Managing an encounter with a stranger, for example, requires the engagement of a variety of social cognitive processes. We consider what we know of people with similar characteristics, we think about past encounters of a similar nature, and we consider contextual cues that have a potential influence on the nature and outcome of this encounter. For younger adults, this analysis may elicit a stereotype that is then applied to the encounter, but it may also lead to thoughts about how this individual is unlike the stereotype one holds of his or her group, and how previous encounters with strangers are unlike this one in a variety of ways. Older adults, on the other hand, seem less likely to engage in this complex analysis and more likely to rely on previous experience and ready stereotypes to help them through the new situation.

Researchers have suggested a number of explanations for this age difference in social attribution. One possibility involves the interaction of available social schemas and the lessening of cognitive resources. Older adults have accumulated a rich repertoire of social scripts to apply to social encounters. Applying an existing schema requires less cognitive effort to select and apply than the development of a novel approach. Slower and less efficient processing of information may make it difficult for older adults to alter highly scripted forms of social behavior and adapt them to a new situation. They are more likely to process information automatically because of the cognitive demands required of new interpretations. Other researchers, however, have cautioned that this explanation should not be accepted uncritically. They have instead suggested that a variety of social factors influence how an individual will attend to and process information. Attitudes, values, and motivational goals that are more directly connected to context, cohort, and gender than to development have a significant impact on social functioning.

Socioemotional Selectivity

A consideration of the motivational goals of older adults is the underpinning of Carstensen's socioemotional selectivity theory. As adults age, they accumulate social losses through the death of members of their networks and through events such as retirement. This explains, in part, why older adults have fewer social relationships than young people. However, this simple explanation does not consider the role of individual agency or development in producing smaller social networks in later life. Early theorists in the field of social gerontology proposed that a developmental process called disengagement was responsible for initiating a process of withdrawal from social roles, relationships, and responsibilities. This process, begun in mid-life, was considered a desirable and natural part of growing older. In turn, social policies such as mandatory retirement were considered to be consistent with this approach to successful aging because they promoted the withdrawal of older people from the social roles common to earlier points in the life span. Disengagement theory generated controversy, but received little empirical support and was widely disregarded.

Socioemotional selectivity theory picks up on the idea that older individuals are, in part, responsible for their shrinking social networks and that this process is potentially age linked and adaptive. However, there are important differences between selectivity and disengagement. Across the life span, people are motivated to seek social contact for reasons such as information seeking and emotional gratification. These motivations show general age-related patterns. In later life, emotional goals are prominent. For example, older people prefer and seek out emotionally rewarding social encounters with old friends rather than novel interactions with strangers. Younger people, on the other hand, are motivated to expand their networks by maximizing the greatest number of new encounters.

Carstensen believes that the same socioemotional goals guide all of us through life, but that the priority of these goals changes for one important reason: the perceived time left in life. When our horizons are far away and ever expanding, we seek out relationships that add information and novelty and contribute to possible futures. When our horizons are close and our time on earth seems limited, we are much more present oriented and consciously seek out emotionally gratifying and meaningful encounters. This explains why older adults are not as willing as younger people to seek out new relationships, even when they have lost significant numbers in their old networks.

Unlike other developmental theories, the selectivity approach does not require that certain socially motivated behavior be restricted to a chronological period. There is evidence, for example, that younger adults experiencing serious or terminal illness also show a preference for emotionally satisfying versus cognitively challenging relationships. They are highly selective in their choice of social partners and prefer those who are familiar. Consistent with the tenets of the theory, foreshortened time seems to have altered social motivations and goals. Presumably, adults of any age who learned that they were likely to live longer than expected might show the opposite pattern, i.e., a preference for novel encounters and challenging interactions.

Collaborative Cognition

Are two heads better than one? Researchers concerned with the early part of the life span have found considerable evidence that children collaborate with others in play and problem solving and that this collaboration plays a decisive role in cognitive development. The thinking of the Russian psychologist Vygotsky has been influential in guiding this research. From his sociocultural perspective, cognition is not always an individual activity, but often the joint activity of a dyad. Partners – for example, a parent and child – collaborate or distribute a task in a way that creates a zone of proximal development that supports and guides the child's gradual learning and mastery of a skill.

This approach to cognition seems to hold promise for understanding cognitive functioning in later life as well. If processing capacity declines with age in most adults, then perhaps a way to optimize functioning is collaborating with others on cognitively demanding tasks. This is the thinking behind recent research on collaborative cognition in later life. The benefits and costs of collaborating on memory tasks and problem solving have been considered. In general, researchers have found that older adults can help each other with story recall, decision making, and problem solving. When they do so, their performance is typically better than the average performance of their age peers. Indeed, in some research, the memory performance of older participants rivals that of younger adults when they are permitted to collaborate. They appear to use jointly constructed recall processes to enhance their recollection of the target information. In other words, the cognition of older adults may be improved through social interaction.

The effects of collaboration have also been found in activities less directly connected to basic cognitive processing, for example, in the promotion of wisdom-related behavior. Researchers have found that wisdom potential could be activated when the discussion of a standardized wisdom dilemma occurred with an intimate partner or even with a virtual partner in an imagined discussion. Other work has carried this investigation further by considering the real-life dilemmas of adults of various ages and how they attempted to resolve them in collaboration with others.

In a series of studies, researchers asked adults to report on life problems for which they "didn't know what the right thing to do was." Problems ranging from simple and conventional – selecting paint colors for a room – to those more complex and moral in nature – the ethics of euthanasia – were reported. After discussing the problem, participants reported on how extensively and with whom they had consulted. A large majority of these adults consulted with at least one other person about their problems. Even more interestingly, those who consulted widely with others also described their dilemmas in a more complex fashion than those who had not done so, were more satisfied with the solutions they developed, and were less likely to be highly authoritarian in their personality style.

Why does social collaboration have this effect? Research has shown that less complexity in discourse about personal problems is linked to indicators of problems associated with aging, such as lower levels of education and support. Using a sociocultural interpretive perspective, the activity of collaborating about issues and problems can be seen to affect the way they are mentally represented by the individual. Real, imagined, or anticipated conversation might lead people to elaborate more complex presentations of a problem. This complexity of thought would be triggered by the need to consider multiple perspectives: one's own and one's conversational partners'. Such a collaborative process is more likely to be undertaken by those open to considering a wide range of perspectives, for example, those less authoritarian in their viewpoints, and tends to produce a solution that is more satisfying for the problem solver.

Morality

Morality is about the judgment of behaviors and relations with others, not just their cognitive representation, as in the other domains of social thought reviewed here. Much of the research to date on moral development has focused on levels of thinking about courses of action in social situations in which the needs and rights of others and/or the self come into conflict. In addition to this focus on judgments about right and wrong, however, morality is also about behaving consistently (or not) in relation to these personal judgments. In order to make a moral decision, one must appreciate the problem, reason about how to solve it, focus on the values that support a choice, and stick to the decision while carrying it out.

Consequently, it is important to consider moral thinking or reasoning in this larger decision-making context when trying to understand how it develops across adulthood. Moral reasoning appears to be an aspect of social thought that shows considerable development from childhood into mature adulthood. Research on stages of moral reasoning suggests that education and life experience encourage people to move further along in the standard sequence of development that has been described by Lawrence Kohlberg and others. Longitudinal studies with older adults have shown that the levels of reasoning that people can achieve about both standard dilemmas and personal moral problems show advances into middle age, and then tend to plateau and do not decline systematically, at least up until age 75.

How does this moral reasoning capacity relate to people's actual decision making in personal life? Older adults may be less likely to consider systematically the viewpoints of others in a situation when initially gathering information in order to make moral judgments. They also have been shown to prefer less detailed and more generic information about others when they have to make decisions. Nevertheless, in general they do then reason about

information regarding others' needs and rights in ways as sophisticated as those of their midlife and young adult counterparts. They are also equally likely to select moral and prosocial values as their guidelines in making choices in real life. As with other areas of social cognition, older adults may demonstrate some limitations due to processing resources, but still seem well able to cope with the demands of a complex social environment.

Positive Psychology and Well-Being

Though much psychological research traditionally has focused on problems and maladjustment, recently there has been more interest in positive psychology, qualities that promote personal well-being across the life span. In this section, several of the positive aspects of later life social cognition that have received attention within personality psychology are briefly discussed. These include generativity, ego integrity and coping, optimism and perceived control, and wisdom.

Generativity refers to a concern for and commitment to future generations that is typical of a positive style of adaptation in midlife, according to the ego stage model of Erik Erikson. Recent thinking, however, has called the staged nature of generativity into question. It appears that older adults retain caring for future generations as an important life goal. Research has shown that the use of family stories in teaching the young, and family engagement with the grandchild generation, are nurtured by stronger levels of personal generativity. In turn, generativity predicts more satisfaction and a stronger feeling of having learned lessons in life during the later stage of Erikson's model, ego integrity.

Ego integrity represents the individual's capacity to feel a sense of accomplishment with regard to the past and the end of life. Reminiscence is an important function of later life, and appropriate styles of such reminiscence about social life can be integral to successful adjustment and achievement of ego integrity. It is also striking that although there are losses that must be dealt with as people age (e.g., health, physical capacities, and memory skills), they generally report no decrease, and sometimes even improvement, in their sense of life satisfaction. Research suggests that although people may have fewer resources in life, they manage to balance these limitations by being more selective in the life goals that they choose to pursue (similar to findings about socioemotional selectivity described previously). Such selective optimization may help individuals to cope with the challenges of aging.

Optimism is a quality that has been studied in several ways within positive psychology, including the kind of explanations that people typically give for past and current outcomes, as well as the more traditional sense of expecting good things for the future. There is convincing evidence that optimism (vs. pessimism) tends to be associated with more persistence in dealing with problems and with better health outcomes when dealing with disease in early adulthood and midlife. This is likely due at least in part to more positive expectations for the future, including one's social encounters. High levels of pessimism appear to predict less subsequent happiness and more health problems among older adults, too. However, pessimistic explanatory styles may not be so clearly maladaptive in later adulthood, because they may serve as a more realistic way of coping with life problems over which older adults do indeed have less control. Nevertheless, increasing older adults' sense of perceived control over their own lives has been shown to have positive benefits, particularly among those in highly impoverished environments such as traditional nursing home settings. It seems that for the most part, realistic optimism and a sense of self-control are beneficial in later life.

Wisdom is a complex idea with a long cultural history, but generally implies some sort of expertise in solving the difficult practical questions of how to live well. Such a skill is, by its very nature, fundamentally social in character. There is a positive stereotype in many cultures that wisdom is a capacity that grows into later life, unlike so many other cognitive skills. Consistent with this stereotype, adults generally judge themselves to have become wiser with age. When objective ratings of wisdom by observers are used instead, there is not quite as clearly an aging effect. This research suggests significant individual variation, with these skills developing into adulthood and then being maintained quite well into later life. In some studies, people have tended to agree on what constitutes wise advice on a personal problem. This suggests that there is some general sense of a wisdom construct, that it is distinct from cognitive complexity, and that it is related to a balance of cognitive and emotional considerations.

One prototypic aspect of wisdom that has been investigated is advice on child rearing. Older adults did not do as well as younger or middle-aged adults on hypothetical problems given to them, but when asked to discuss their real-life problems, they performed as effectively as other age groups. Consistent with the previous observations about social context, wisdom is often manifested in social contexts, and interactions among people (even imagined interactions) can produce better performance than that of

individuals responding alone. Collaborating on the solution to a problem in later life, it seems, is a useful strategy whatever the nature of the concern.

Conclusions

Much of the research literature on basic cognition in later life points to possible losses over a wide variety of domains such as memory, communication, and decision making. This body of work has focused on information-processing abilities and capacity and has typically been carried out in an environment designed to minimize the effects of the social context. Age differences demonstrated in these traditional experimental studies usually have been interpreted with reference to inevitable biological decline. A social cognitive perspective, on the other hand, leads us to consider how, and how well, older adults function in their social worlds. Following from the pioneering work of Vygotsky on child development, researchers interested in social cognition in later life assume that development is rooted in social processes across the life span. Cognitive losses may be likely as one ages, but there are also gains, and they are both significantly affected by the social context.

This article reviewed the most influential findings in the study of social cognition in later life. In general, researchers have been interested in the kinds of social environments that older people manage or construct for themselves. They have considered what effect declines in cognitive capacity might have on the social thinking and behaviors of older adults. The areas of research from which these findings are drawn target basic social processes: how older people perceive and evaluate other social actors and are evaluated in return; how the perception of one's life and time left in that life affect motivational goals; how social resources can be used to compensate for declining or inadequate cognitive resources; how older adults judge the characteristics and actions of others in arriving at a decision about action; and how well-being can be linked to styles of thought, social appraisal, and perceptions of events. Taken together, a growing body of research on social cognition in later life paints a complex portrait of the average older person as intentional and well-functioning in his or her everyday social world despite the undoubted challenges provided by shrinking social networks and reduced cognitive resources in later life.

See also: Adaptation; Ageism and Discrimination; Psychological Well-Being; Reminiscence; Social Networks, Support, and Integration; Speech and Communication (speech styles); Work and Employment: Individual.

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Social Networks, Support, and Integration

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Glossary

Buffering Effects of Social Support – Social support buffers or reduces the effect of stress, life events, or crises on an individual's quality of life, well-being, or health.

Convoy Model of Social Relations – Describes how an individual moves through time, age, and history, affecting and being affected by others who have fundamental influences on the individual's development and well-being.

Health Continuum – The continuum of health from a disease-free state through disease onset or health crisis (e.g., heart surgery), to recovery, rehabilitation, or death.

Life Span Developmental Theory – This perspective argues that it is critical to understand the effect of inter- and intra-individual development over time in order to truly understand the individual at any one point in time.

Reciprocity – In the social support literature, used to refer to reciprocal exchanges, that is, exchanges seen as equal in the amount of support provided and received by each participant. Exchanges can be non-reciprocal. Reciprocity is considered the general norm of social relations across most societies.

Social Integration – The degree to which an individual is embedded into the group, organization, or community. This term considers the centrality versus marginality of the individual to the majority group.

Social Networks – Structural characteristics of an individual's social relations. Social networks include the objective aspects of social relationships such as network size, age, sex, relationship (e.g., husband, friend), and frequency of contact.

Social Support – Exchange of instrumental and emotional resources such as money, goods, services, information, and love among social network members. Both the provision and receipt of these exchanges have been studied.

Support Bank – In keeping with the general norm of reciprocity, the support bank describes a type of unconscious savings account through which people build reserves through non-equitable relationships by providing more support than they receive (i.e., making support deposits into the support bank) so that support will be available to them at some time in the future when they are needed (withdrawals).

Introduction

Social relations has been increasingly recognized as a critical element in the adaptation, adjustment, and well-being of older people. Since the mid 1980s, the theoretical basis for the study of social networks, support, and integration has expanded considerably and has significantly benefited from an accumulation of empirical evidence. This article provides an overview of the theoretical and conceptual issues that have guided the research, a consideration of methodological limitations and advancements, and

illustrative examples of the empirical research now available in the field.

Theoretical Issues

There is considerable consensus that a long-term, life span view of social relations is critical for a full understanding of how social relations develop over time and influence other aspects of an individual's life. The convoy model of social relations offers such a life span view, explaining how social relations develop over time – optimally maximizing the individual's health and well-being. The convoy model describes how people's personal (age, race, gender) and situational (roles, environment, circumstances) characteristics both shape and determine the nature of social relations experienced. Social relations, in turn, affect people's health and well-being. Convoys grow, develop, and change with the individual and, under optimal conditions, help, support, and socialize people, providing them with a firm base from which to face the challenges of life. Unfortunately, convoys of social relations are not always optimal and under some circumstances can make individuals more vulnerable to stress, health problems, and poor well-being.

A related theory, the socioemotional selectivity theory, also takes a life span perspective, suggesting that people's goals and aspirations with respect to social relations change over time. This theory proposes that young people, who feel they have a long future ahead of them, are likely to seek out new relationships and continually expand their social networks. As people get older, however, they become more selective about the relationships they wish to maintain. With age, the theory argues, people wish to maintain relationships only with those significant others with whom they have a good relationship. They are, therefore, less likely to seek out new relationships and more likely to deeply invest in the ones they value.

Recent theoretical perspectives regarding social relations have suggested the importance of moving beyond description to a more fundamental understanding of the process by which social relations affect health and well being. The support/efficacy theory suggests that social relations affect health and well-being by instilling in the individual a sense of self-worth and self-efficacy. In essence, an optimal convoy of support communicates to the individual that he or she is a person of value and worth, of ability and skill. Significant others communicate that they believe the individual is capable of successfully meeting the challenges confronted in life. This consistent feedback of expectation of success eventually results in the individual's accumulated and internalized feelings of competency, success, and well-being. Of course, not all people have this type of positive support network or convoy. Under less optimal conditions, social relations can threaten and undermine people, constantly making them feel less competent and less able and, thus, unable to successfully confront the problems or challenges they face. Rather than improving their health and well-being, such convoys of social relations can only serve to make the individual feel less worthy and less able, in short, less efficacious. It should be noted that often convoys are neither completely positive nor completely negative. It is more likely that a convoy consists of both positive and negative characteristics, with some convoys including both supportive and non-supportive members and others including convoy members who are able to provide support in some areas and thus increase efficacy in these areas but not in others.

Another theoretical perspective suggests that the most important aspect of social relations is the fact that they help the individual learn how to regulate his or her emotions. This emotion regulation perspective suggests that people learn from their interactions with others how best to control their own emotions, specifically how best to manage and regulate both their positive and negative emotions. This self-regulatory ability allows the individual to more competently navigate the challenges and choices confronted in daily life, thereby optimizing outcomes and overall well-being.

Definitions of Critical Terms

Three terms central to the study of social relations, social network, social support, and social integration, should be clearly defined. Early research frequently blurred the distinctions between these concepts, thus limiting the potential for theoretical advances. The term social network refers to the structural or objective characteristics of the social relationships maintained by the individual, e.g., the number of people in the network, their relationship to the older person, and their age, frequency of contact, and density (i.e., how many network members know each other). Social support refers to the actual exchange of different types of support such as aid, affect, or affirmation within the relationship. Examples include tangible exchanges such as lending money or caring for the sick, or emotional support such as love and affection. And, finally, social integration refers to the degree to which the individual, usually by virtue of social relations with others, feels integrated into the community specifically and society more generally. It is often labeled as

'belongingness' or 'embeddedness' in the literature. Social integration is the exemplification of adaptation, adjustment, and general well-being and might be considered an outcome of optimally functioning social networks and social support.

The term social relations is an umbrella term for the three previously defined concepts. An important issue when considering the role of social relations in the lives of the elderly is the processes through which social relations operate. Two effects of social relations have been identified, described, and investigated. The first, known as the direct or main effect of social support, suggests that having friends and family who think highly of you make you feel good about yourself, which therefore fundamentally improves your adjustment, adaptation, well-being, and mental health. The second is known as the indirect or buffering effect of social support; it suggests that social support is most effective once the individual is confronted with a problem or stressful life event. Under these circumstances, friends and family help the individual, through social support, to cope with problems or crises they encounter. Thus, support from others buffers the impact of negative events, crises, or stresses in the individual's life, thereby improving his or her adjustment, adaptation, well-being, and mental health. Empirical evidence has documented both types of effects.

It is likely that individuals experience direct and buffering effects of social relations. Individuals accumulate relationships over time as well as specific support exchange histories, both of which influence their perspective on current relationships. Although early relationships do not completely predetermine later relationships, it does seem likely that people develop styles of relationships and expectations about them. There appears to be a cumulative element to important, close, enduring relationships that permit the development of expectations concerning reciprocity of exchanges. And, finally, although there is a tendency to assume that social relations have both long- and short-term positive effects, it is important to recognize that these relationships, and expectations about them, may also be negative. Thus, an older person who becomes ill might expect help and support from a spouse or daughter, or, based on previous experience, might realistically recognize that they are unreliable sources of support, especially in times of crises.

Measurement Issues

Measurement has been a weak link in the empirical study of social relations, thereby affecting the quality of the available data. Early measures were often vague and non-specific. Network measures have been considered support measures, and questions that ambivalently assess support concepts have been interpreted definitively. Thus, for example, a network question that establishes marital status has been interpreted as evidence of social support (i.e., the receipt of emotional support from a spouse). However, it is clear that having a spouse does not guarantee that the spouse provides support. An older person might have a spouse, but the quality of the marital relationship might be so poor as to preclude spousal support or the spouse might be too sick to provide any type of support. Measures might be role driven or affect driven, and the reliability of these measures can be quite different. Research has shown that role-based measures of social relations are most reliable. Obviously, if an older person is asked whether they have children, the answer is not likely to change over time and thus is quite reliable. However, an affectively based measure of the relationship can be less stable. How close one feels to one's adult child, for example, may change over time. The child might move out of state, the two might have an argument, or the child might disagree about a specific healthcare or lifestyle choice made by the elder (or vice versa). Under these conditions, how close the older person feels to his or her child could change radically. This change should not be misinterpreted as a lack of measurement reliability.

Although empirical evidence indicates that there can be considerable differences among the existing network and support measures, it should not be assumed that this problem has a simple solution or that a 'correct' measure of these concepts exists. In fact, the most 'correct' measure may not be solely based on psychometric criteria but rather also considering the theoretical or conceptual purpose of the study. Thus, if the purpose of the study is to identify the structure of a social network of an older person, a simple network assessment by measures such as the number of network linkages and social contacts would be most appropriate. However, if the purpose of the assessment is to design an intervention strategy or assess the supportive potential of specific relationships, it would be critical to assess both the affective as well as instrumental aspects of the relationship. For example, if attempting to develop a discharge plan for an elderly person recovering from a stroke and facing an intense rehabilitation program that requires significant assistance with activities of daily living, it would be critical to determine whether the elderly person has children, whether they have a good relationship, and whether the children are available to help with the elderly person's rehabilitation once he or she is discharged.

Knowing that the older person has ten adult children does not necessarily answer the question of their availability, either emotionally or instrumentally, to provide support. For the most part, researchers now understand that there are different types of social relations, each of which, under most circumstances, must be measured separately. It is also clearly recognized that deciding which measure is optimal depends almost entirely on the research question being asked.

Data Sources

Social relations interest scientists come from a wide variety of disciplines, each of which uses diverse approaches to study design and sample development. Anthropologists, sociologists, psychologists, epidemiologists, psychiatrists, and gerontologists have studied social relations across the life span generally and among older people specifically. Thus, major studies in the field incorporate very different types of samples, a fact that is fundamentally important when assessing both the quantity and the quality of what is known about social relations. Anthropologists have used ethnographic techniques to study social relations among select small groups of people, whereas epidemiologists have studied thousands of people who are randomly selected to represent designated segments of the population. Clinically based samples might study people being treated for a specific disease or inpatients with a specific medical diagnosis. Some samples are very small but are studied intensely, while others are exceedingly large with only a few questions addressing the topic of support relations. Similarly, a body of empirical evidence is now accumulating targeted at people at a specific stage of the life course, such as mothers and infants, school-age children, young and middle-aged adults, as well as older people. Although there may be some lifetime continuity in relationships, it should not be assumed that evidence based on a sample of younger people can be applied to specific issues of concern among the elderly. For example, the evidence that a school-age child is most advantaged by instrumental support from parents may provide general information about the importance of family, but cannot be unconditionally generalized to the elderly or to a specific older person. Whereas the young might feel comfortable, for example, receiving financial support from their parents, assuming it to be developmentally appropriate, an elderly person might not feel comfortable receiving money from a child. The older person might consider it developmentally inappropriate, indeed a symbol of failure, to take money from one's children rather than being able to provide it. Similarly, knowing that the social relations of those suffering from schizophrenia are characterized by certain patterns may or may not provide useful information about older non-schizophrenic people.

In sum, application and relevance of previous research to the elderly should be assessed with an awareness of both sample quality and population characteristics of the previous research. These issues affect the degree to which research findings are applicable to the elderly or, for that matter, to any specific population of interest.

Social Support and the Health Continuum

A final conceptual issue to consider before reviewing current empirical evidence is the role of social relations at different points on the health continuum. Although health is a major concern among many elderly people, there is clearly a health continuum. Health among the elderly can vary from healthy with few or no health problems to terminally ill with significant comorbidity. There is a great deal of research that argues that social support influences health and well-being. However, it is not appropriate to assume that the same type of social support will meet the needs of the elderly at all points on the health continuum. The healthy elder might need a companion to share an exercise regimen, whereas the terminally ill might need someone to simply sit with them, provide emotional support, or help with the final disposition of their affairs. Elders in an acute health crisis might need someone to recognize the crisis (e.g., recognize abdominal or chest pain as a heart attack as opposed to indigestion) and provide the instrumental support of a ride to the hospital. Similarly, people who have experienced a myocardial infarction might best be supported by individuals who tell them they are tough and able to complete the rehabilitation program as well as to successfully adopt the lifestyle changes required. Support can operate directly or indirectly to affect health and well-being. Although general positive feelings from close and important others are likely to promote overall well-being in the face of a specific crisis or event, types of support, no doubt from specific others, are likely to be the most effective resources. This point is made to emphasize again that the most appropriate methodology for any study must match the goals of the study. There is no one perfect measure that can assess social relations, network, support, or integration under all circumstances for all elders.

The next sections consider the empirical evidence currently available concerning social relations among the elderly. Five bodies of empirical evidence are considered: family and friendship relationships,

social exchange and reciprocity, gender differences, cultural differences, social relations, and well-being.

Family and Friendship Relationships

The study of social relations in adulthood and old age has frequently been divided into family relations versus friend relations. Although early work often described the broad inclusive categories of family, friends, and neighbors, most current research pays more careful attention to the specific relationship. The social support exchanged with specific people has been shown to impact the health and well-being of the older adult. For example, older people who are married are much less likely to need formal supports, such as home nurse care or Meals on Wheels, than unmarried people. Although it is clear that families play important roles in the lives of older adults, providing sometimes extraordinary caregiving efforts and instrumental help, friends are also invaluable resources. Indeed, research initially designed to examine the impact of family members alone often finds that the friends are mentioned as a significant support source.

Initial studies documented the structural characteristics of social networks. It is known from early cross-sectional studies, for example, that younger respondents have more frequent contacts with network members than older respondents, whereas older respondents have known their members longer. Most networks of older people consist of family members, primarily spouses, children, and siblings. Friends, however, often play an important role in their support networks.

Generational differences in network structure and support patterns have also been examined. Older generations include more family members in their networks, whereas younger generations include more friends. Nevertheless, both younger and older family members are named as closest network members, with friends and more distant relatives as somewhat less close. Significantly more support from friends is often reported by younger respondents, whereas middle-aged respondents report more support from family. However, research has shown that when nuclear family members are not present in the social networks of older adults, other close relationships seem to be substituted. This especially appears to be the case for instrumental support. Thus, while friends do not replace family members, they do play an important role in the lives of older people.

In one study of friendships among people over 60, 68% reported long-term friendship ties throughout their lives. There were some gender differences, with more than half the women reporting that they remained friends with a close friend from childhood or adolescence, whereas men showed high levels of continuity with close friendships developed at midlife. There seem to be constraints on and changing definitions of friendship among the 'oldest-old.' In one sample of people over 85 years old, it was found that more than half still had at least one close friend, and three-fourths were in weekly contact with people they considered their friends. Furthermore, almost half reported that they had made new friends after age 85, although the criteria for those friends tended to involve less expectation for intimacy or shared history than was common among younger people.

Studies of support from kin and friends have highlighted the importance of recognizing differences in these relationships. Although research focused on the exchange of social support is more limited, it does seem clear that differing degrees of support are provided depending upon the closeness of the relationship. Spouses/partners are usually rated as most supportive, but best friends and children are also rated as very supportive, significantly above all other categories. Compensation in the event of the loss of a major support person has been investigated as well. It has been found that children, friends, and acquaintances compensate for the loss of a spouse with increased emotional support to the widow. Some protection from loneliness seems to be provided by children and friends, at least for respondents without partners.

Although spouses provide the most support overall, and adult children often give instrumental support, siblings may have a distinct place in the lives of older adults by bridging aspects of both family and friend relations. Continued sibling contact provides opportunities for life span socialization. An interesting race difference is evident among White and African American sibling pairs. White sibling relationships appear to range from very positive, intimate, and congenial to quite negative and hostile. African American sibling pairs, however, exhibit primarily positive interaction patterns. Other studies of siblings indicate that a large number of older people consider their sibling a very close friend. Sibling ties, among the longest social ties in most older people's lives, are the most egalitarian and friend-like of all family relations. Nevertheless, important differences remain since siblings are fundamentally family members.

Studies indicate that most elderly receive substantial support from others. Nevertheless, there is some indication of a pattern suggesting that more support is received from fewer people as people age. This has often been interpreted to be the result of increased physical or functional limitations. Recent theoretical perspectives, however, have offered additional

explanations. Several studies have indicated that there are age differences in how family and friends are valued, with older respondents indicating that friendships increase in importance as compared to younger respondents. Adequate longitudinal data are not yet available to address the question of the changing value of relationships over time, though there are at least two theoretical positions that are suggestive. As noted previously, both the socioemotional selectivity theory and the convoy model predict that close and important friend and family relationships will remain so into old age, and the socioemotional selectivity theory specifically predicts that more superficial relationships are likely to dissipate. Alternatively, because life transitions often provide different opportunities and circumstances, some ties, especially those with friends and siblings, may take on renewed importance as individuals emerge from earlier obligations.

One consistent, almost universal, finding concerns the reported quality of social relations among family and friends. Older people are much more satisfied with the support they receive and with their support network more generally than younger people. One possible explanation is that as people get older they are more likely to evaluate various aspects of their environment positively. Indeed, survey researchers have noted that older people show consistent increases in life satisfaction with age but a leveling off of more affective characteristics such as happiness.

Recent research has examined profiles of social networks, that is, different clusters of social network members. These profiles range from limited family (e.g., spouse only) to more extended family (including spouse, children, and other relatives), isolates (people with few social relations), and diverse profiles (including both family and friends). Interestingly, in these studies of both middle-aged and older adults, people with diverse networks that include significant involvement with both family and friends report the highest levels of well-being, while those with restricted networks consisting of very few people, e.g., just a spouse or very few family members, report the lowest levels of well-being. These findings demonstrate that the ostensible ideal circumstance, i.e., that of older people surrounded by a select few close family members, may no longer be ideal, especially for healthy elders. Interaction with numerous and diverse network members is associated with subjective well-being among the current population of elders, but isolation or limited interactions with others is not. Additional research is needed to examine whether the same profiles are optimal under different circumstances, e.g., among those facing a serious illness or death.

Social Exchange and Reciprocity

To explain the nature and impact of social support requires that consideration be given not merely to its existence, but also to the ways in which it is structured and understood. The concept of reciprocity is central to theories of social support and is approached in terms of the rules that govern support exchanges as well as in terms of the norms that characterize specific types of relationships. In characterizing rules, the theoretical distinction has been drawn between balanced and generalized forms of reciprocity, whereas in characterizing relationship norms, the related theoretical distinction has been drawn between exchange and communal orientations.

Equity theory has provided an overarching theoretical basis for much of this line of research. Equity theory posits that reciprocity is the most equitable status of exchange. It argues that overbenefiting (i.e., receiving more than providing) and underbenefiting (providing more than receiving) are both less than optimal situations, often resulting in guilt or resentment. A life span perspective adds the possibility of assessing reciprocity either in explicitly contemporary terms (balanced reciprocity) or in longitudinal terms (generalized reciprocity). There is evidence in support of both types of reciprocity. Reciprocity within superficial or recent relationships (exchange relationships) is more likely to be short term and immediate. On the other hand, among relationships that share various aspects of life and that have endured over many years (communal relationships), older persons are more likely to use a long-term accounting system. In the former case, one might return a borrowed cup of sugar after the next trip to the grocery. In the latter case, however, one might provide intense sick care for a spouse and expect no immediate return, rather feeling assured that if a similar need arose in the distant future, that spouse would provide the same care. It has been suggested that people maintain an unconscious 'support bank,' much like a savings account, in which they keep track of who owes them and to whom they owe various types of support. Interestingly enough, in Western cultures, most people, even old people, report that they give slightly more than they receive. It appears that the preferred state is what exchange theorists would term the underbenefited state, but what the support bank perspective would consider significant savings or deposits.

Dramatic increases in life expectancy during the past decades have resulted in rapid growth of the oldest-old (80+) population. This segment of the population continues to grow. From an exchange theory perspective, the problems of the oldest-old are that, as a statistical aggregate, they have a lower

income and poorer health than younger people. Consequently, they are physically and financially limited in entering into exchange situations. They may no longer be able to afford to exchange holiday gifts with children and grandchildren in the way they used to or to baby-sit grandchildren in return for the help that they receive from their daughters or daughters-in-law. Many have very little of any instrumental value to exchange.

How do such limitations affect their social relations? Currently, there appear to be no commonly accepted rules for support exchanges involving the oldest-old. Some older people withdraw from exchange situations altogether. This is clearly a coping strategy used to maintain reciprocity. They simply choose not to enter exchange situations, thus preventing the non-reciprocal relationships that would result because they do not have the resources to reciprocate. Other older people apply the long-term reciprocity notion of a social support bank in the face of diminishing commodities. Thus, they can receive a great deal of support from close and important others, potentially for an extended period of time, and yet not feel indebted. In this case, older people can assume that they are simply receiving support due to them from people to whom they have provided support in the past. Some exchange theorists argue that even in contract-oriented societies, such as the US, non-contractual relationships are not completely absent. No longer bound by the norm of reciprocity, older people sometimes benefit from the norm of beneficence (i.e., the provision of support from people with more resources to those with less resources). The continuous growth of the oldest-old population urges modifications of the conventional support exchange rules and the emergence of new rules that are most suitable to the aging society.

Gender Differences

Empirical evidence concerning gender differences in social relations has been accumulating. Originally, these gender differences were assumed to favor women. More recent research has suggested that the question might be considerably more complicated. There tend to be relatively few gender differences in the support networks of men and women. Greater similarity is likely to be obtained if the assessment method focuses on close and supportive others. This is the case because most people list family members (i.e., parents, spouse, and children) as their close and supportive others. However, even these structural characteristics tend to become slightly female-biased when focusing on the oldest old because of women's significantly greater life span.

Greater controversy, or at least complexity, arises with the provision and receipt of social support. When considering specifically who provides what, to whom, and how much of it, greater gender differences are likely to arise. Men tend to report receiving support from and providing support primarily to their wives. Women, in addition to support exchanged with spouses, also tend to provide and receive support from a much larger array of people, including children, other relatives, and friends. Men tend to provide instrumental support, especially financial, while women provide both instrumental (services) and emotional support.

A similarly interesting gender difference exists in terms of the interpretation or perception of support interactions. Women appear to feel greater involvement with most of the people in their networks and feel a greater sense of responsibility concerning the resolution of needs or conflicts among their support network members. Thus, although there is a tendency toward same-sex friendships, both men and women are more likely to mention women as confidants. Such gender differences in the nature of relationships, which are observed across the life course, are directly linked to sex roles in this society and indicate a lifelong impact of socialization on the social relations of men and women. Other research has shown that even when data are from both members of an older couple, reporting on the provisions and receipt of support between them, it is clear that there are significant differences in what men and women report concerning support exchanged with spouse.

These support differences and the discrepancy in the life expectancy of men and women portend important differences in the social relations of older men and women. On the one hand, men are much more likely to be married when they get older. With marriage, social relationships are likely to remain relatively stable and intact. On the other hand, if an older man becomes widowed or has never married, he may find himself in a particularly precarious position with regard to social relations. Single men are more likely to be socially isolated than single women, and are much less likely to replace or be able to sustain the relationships previously maintained by their spouse. The exception to this, of course, is if the widowed man remarries, which then reconnects him to a social network through his new wife. Demographics suggest that older women are quite likely to be widowed. Although widowed women are vulnerable in many ways, they are also more likely to have the skills to continue to maintain social relationships. They may turn to other family members and friends to assist with difficulties that emerge, such as the physical limitations and illnesses that sometimes

accompany old age. Nevertheless, older women of today have lived a relatively traditional lifestyle, which might mean that in old age they find themselves with less money and less access to powerful others or community status than they did when they were respected wives of men well established in their community. One can assume that this will change as women begin to enter old age with a lifetime of experience as members of the labor force and with greater independence in their general lifestyle.

Cultural Differences

The literature has documented some variations in social networks and social support across different societies. Different social structures across societies result in variations in the support networks of older persons. Most notably, different family structures directly affect the social networks of older persons. For example, in societies in which large extended families live together, an entire support network often consists of family members who provide all the support an older person needs. In societies such as the United States, where a larger proportion of the elderly live with their spouse or alone, friends and neighbors are also a vital part of the support network. In most societies, women of younger generations provide support to the elders, but the focal support person may vary by society. Thus, for example, in the United States, this person is usually a daughter, whereas in Japan, due to the structure of the family and living arrangements as well as tradition, this person is more likely to be a daughter-in-law.

Different societal norms influence support exchanges. Reciprocity is the basic rule of support exchanges in most societies. However, specific applications of the norm of reciprocity vary among societies. In the United States, the primary exchange rule of middle class Americans prescribes exchange of support in kind and of equivalent value in a relatively short period of time, especially among non-family members. This rule suppresses one-way transactions of support and thereby reduces the development of dependence, which often leads to the disturbance of stable relationships. By contrast, the exchange rule for close relationships in Japan inhibits complete repayment in support exchanges, thereby maintaining indebtedness and dependence. It consequently serves to sustain relationships based on dependence. This comparison illustrates how the general norm of reciprocity regulates support exchanges in the two societies in quite different ways, yet serving the same goal of maintaining the solidarity of support networks. Data are also available concerning reciprocity among the French elderly. They, too, maintain a norm of reciprocity. In fact, compared to American elderly, a slightly higher percentage of French elderly report reciprocal relationships. However, if a relationship is reported to be non-reciprocal, the French elderly are more likely to say they receive more support than they provide, whereas American elderly tend to report they provide more support than they receive. These findings suggest that there are cultural differences in the optimal level of balance between provision and receipt of support, even among Western societies. American elderly appear to consider it most desirable to maintain slightly overproviding relationships both because 'being a giving person' is valued and reinforced in American society and because it ensures having someone available to provide support if there is need in the future, 'a deposit in the support bank.' Under the French norm, however, it appears to be more acceptable to overbenefit (i.e., to receive more than you provide) in old age. Also interesting are gender differences in social relations across cultures. For example, Japanese men are more committed to maintaining harmony and avoiding conflict in their social relations with family, friends, and colleagues. As a result, although Japanese men, like American men, tend to be less expressive than women, unlike American men they are more likely to extend considerable effort toward maintaining good relationships and avoiding arguments or disagreements.

Data examining subgroups within the United States indicate that many more African American than White elderly report reciprocal relationships. Of their non-reciprocal relationships, the majority of African Americans report that they receive less support than they provide. Although subgroup differences in the perceptions of reciprocity within the United States might seem large when only American data are considered, when compared to Japanese and French data, the differences do not seem nearly as great and the degree to which culture influences reciprocity and dependency norms is noteworthy.

Social Relations and Well-Being

Among the most important and impressive research in this area is that documenting an association between health or well-being and social relations. Substantial evidence has accumulated indicating that people who have larger social networks, have more social supports, and are better integrated into the social fiber of their community do not die as soon as others. Similarly impressive research has documented the association between social relations and various forms of morbidity, including cardiovascular diseases, depression, symptom severity, hospital and

emergency room utilization, preventive health behaviors, and successful rehabilitation. Recent longitudinal research has shown that social relations can help people coping with a chronic illness such as osteoarthritis cope with and buffer the effects of social strain on depressive symptomatology.

The exact nature or characteristics of social relations that are important is a controversial issue. As noted earlier, many studies have simply documented the existence of social ties (i.e., the social network characteristics) and demonstrated a statistical association of these measures with health and well-being. However, some researchers argue that the measure of the existence of these ties simply offers a proxy for support exchanges and, by implication, support satisfaction. Thus, being married often suggests that a significant other exists with whom the older person has a close, supportive, and qualitatively superior relationship. Nevertheless, it is important to recognize that this is not always the case; not all spouses offer that kind of support. Researchers have now begun to consider what specific characteristics of support relationships are most important. It is reasonable to assume that each characteristic of a support relationship offers some insight into the nature and functioning of that relationship. Knowing that an individual is married is helpful. It is also helpful to know whether the partners exchange support (i.e., give and receive different types of support such as emotional and instrumental support from each other). But perhaps the most important measure of the effect of social relations on well-being is the individual's evaluation of, perception of, or satisfaction with that relationship. Although some reviews indicate that size of network is the best predictor of well-being, other research suggests that although objective measures such as social network characteristics are useful, the most predictive measures are those that assess the individual's subjective evaluation of the relationship. Research with both American and French elderly representative populations indicates that although both objective and subjective measures of support are significantly related to depressive symptomatology, subjective measures, such as the satisfaction with the quality of the relationship, have a greater inhibiting effect on depression than more objective measures, such as number of social ties. These findings are increasingly supported by similar findings from various countries around the world.

As noted previously, additional evidence suggests that family and friends may function quite differently, although both play important roles in the well-being of the elderly. Family relationships, under normal circumstances, make an important contribution to well-being when conflict is minimal and normal positive relationships are maintained. Under these conditions, older people report relatively stable levels of well-being. When such relationships either do not exist or are conflictual, a negative impact on well-being is usually evident. Another long-standing finding in the literature is that friend, but not family, relations have significant positive effects on the mental health of the elderly. A number of investigations have concluded that family relations, although critical, are assumed, that is, their presence and the support therein provided are normatively expected. When present, no extraordinary positive effect is apparent. However, when absent or conflictual, their negative impact is substantial. The opposite appears to be the case for friendship relations. When not present, few significant negative effects are evident, but the presence of close supportive friendship relations has a significant positive effect on well-being.

Some have discussed the findings on family versus friend support in terms of the volitional versus obligatory nature of the two types of relationships. Although family ties are often prescribed by roles and expectations, friends are free to enter into a relationship, as well as leave it, at any time. Family members are expected to provide support, therefore when they fail to do so or are unavailable, there is a significant negative impact. Friends, however, are not necessarily required by the relationship to be available for support, thus support from friends is perceived more positively. Also, in contrast to family relationships, friends are chosen rather than ascribed, and most often are chosen on the basis of similarity of interest, experience, or personality. The act of choosing one another also brings with it feelings of being admired and liked over others, which also enhances emotional well-being.

Gender differences in the role of social relations and their effect on well-being should also be noted. The well-being of men is more positively affected by marriage than it is for women. Men seem to garner significantly greater benefits from the marital relationship, than women. In fact, women, much more than men, appear to be at risk for the negative impact of this relationship, should the marital relationship be of poor quality. Furthermore, it is clear that there is a significant gender difference in the role of social relations that transcends the marital relationship. Women's generally high sensitivity to poor-quality social relations affects their mental and physical well-being. Additionally, an intriguing finding suggests that although women often report more sources of support in their network than most men, the effect of larger numbers of close relationships is sometimes negative in that these women report being less happy. It appears that although women have more intimate

relationships from which they receive support, they also are more emotionally involved with and feel a need to provide more support to each of their relationships.

As this latter point suggests, it is important to note that there may be negative, as well as positive, consequences of social interactions. Negative social relations are evident in relationships that are tarnished by conflict or negative affect; or in exchanges in which positive support is unasked for or is provided to a degree that is overwhelming and smothering. Similarly, social relations can be assumed to be negative or to have a negative effect on well-being when support is provided for maladaptive behaviors, such as smoking, drinking, avoiding health care, or not taking medications. Thus, the study of social relations must take into account that convoys of close friends and family members may be both pleasant and unpleasant, supportive and unsupportive. These differences, of course, result in fundamental differences in outcomes.

Summary and Conclusion

In conclusion, social networks, social support, and social integration can play a significant role in the maintenance of the health and well-being of an older person. At the same time, social relations represent only one of the many important factors contributing to the well-being of the elderly. Biological and physical factors also play an important role. However, neither exists in isolation, and the bidirectionality of influence is evident. While a great deal of research in recent years has improved our knowledge of both the conceptual and methodological characteristics of social relations, it must be recognized that because of the idiosyncratic nature of social relations, there are no absolutely correct conceptualizations or measures. Social relations consisting of social networks, support, and integration operate at multiple levels through social networks (each member with individual characteristics), social support (involving interpersonal often dyadic exchanges), and social integration (a community or societal connection) have important influences on health and subjective well-being. Research thus far suggests that social relations can improve the overall quality of life of healthy older persons and can serve to improve the experience of the elderly as they face the physical and psychological challenges of aging.

See also: Life Events; Life Satisfaction; Loneliness; Psychological Well-Being.

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Social Security

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Glossary

Currently Insured – When one acquires six quarters of coverage in the 13 quarter period ending in the calendar quarter of death, disability, or reaching age 62.

Fully Insured – When one has earned the minimum number of quarters of coverage, which is 40.

Social Security System – Social insurance programs that provide economic security for elderly persons, disabled workers, and workers' dependents and survivors.

Introduction

The Social Security program enacted under the Social Security Act of 1935 has been hailed as one of the most popular laws since the Great Depression of the 1930s. Thanks to the act and its subsequent amendments, millions of beneficiaries have been able to escape poverty. Despite the popularity of the program, the prophesy by Arthur J. Altmeyer, the chairman of the Social Security Board in the 1930s, is becoming a reality: Social Security is a living document and, therefore, needs to be reformed to meet the changing needs of the population and to make it relevant to the changing economic conditions.

Like other developed countries, the United States has been undergoing enormous changes in demographic composition, family structure, and economic conditions. These changes have led the American people to have second thoughts about the scope of the Social Security program and about some of the regulations that have become obsolete and inequitable.

Reflecting the changing attitudes toward Social Security, the United States started, in 1977, to reform the Social Security program so that it could remain financially solvent. Before that time, the thrust of policy changes was to make the Social Security provisions more generous.

This article (1) describes how the Social Security system works, (2) discusses the demographic shifts and actuarial imbalance, (3) reviews the inequities in the current system, (4) describes the 1983 Amendments to the Social Security Act and the recommendations by the 1994–96 Advisory Council on Social Security and the President's Commission to Strengthen Social Security, (5) and discusses the US income support for the elderly in broader perspectives.

Provisions

The US Social Security system includes social insurance programs to provide economic security for elderly persons, disabled workers, and workers' dependants and survivors – Old-Age and Survivors Insurance (OASI) and Disability Insurance (DI), which together are referred to as OASDI. OASI, established under the Social Security Act of 1935 and its 1939 amendments, is designed to provide cash benefits for retired workers, dependants, and survivors, and DI, established by the 1956 amendments, is designed to provide cash benefits for disabled workers and their eligible family members. Medicare benefits (Health Insurance, Part A and Supplementary Medical Insurance, Part B) are also provided under the Social Security Act. However, because the concept of Social Security popularly refers to OASDI, this article addresses only OASDI.

At the end of 2004, 48 million people (16% of the population) were receiving benefits – 33 million retired workers and their dependants, 7 million survivors of deceased workers, and 8 million disabled workers and their dependants – for a total cost of $493 billion. During 2004, 157 million people had earnings that were covered by Social Security and paid payroll taxes.

The US Social Security system is based on several principles. First, beneficiaries have an earned right to benefits and are not subjected to any form of means test or income test. Second, all workers are compelled to make financial contributions to the Social Security program, unless they are specifically exempt, such as state government employees in the states that have opted out of Social Security or those who vow poverty for religious reasons.

Two principles are involved in calculating benefits: individual equity and social adequacy. Individual equity is implemented by relating benefits directly to beneficiaries' prior earnings. Social adequacy is implemented by providing larger benefits to low-wage workers in relation to their contributions and additional benefits to auxiliary beneficiaries (for example, children, dependent parents, and spouses with little or no earnings of their own) without added contributions.

Social Security is funded by payroll tax on employees and employers and has been financed generally on the basis of the pay-as-you-go principle throughout its history. However, the 1983 amendments included the provision to build up the trust fund's assets in anticipation of the large number of Baby Boomers who will reach retirement age starting in 2010.

There are two types of insured status: fully insured and currently insured. Fully insured means that one must have earned the minimum number of quarters of coverage, which is 40. Currently insured means that one must acquire six quarters of coverage in the 13-quarter period ending in the calendar quarter of death, disability, or reaching age 62. These different insured statuses determine who is eligible for which type of benefits:

- Fully insured *or* currently insured: OASI benefits to workers and their spouses and children
- Currently insured: SI (Survivors Insurance) benefits to workers' spouses and children
- Fully insured and currently insured (for blind persons, only fully insured status is required): DI benefits to disabled workers.

In 2006, one quarter of coverage is obtained by earning $970 during a year. Twice this amount provides two quarters of coverage, and so on, so that when the earnings reach four times $970, four quarters of coverage can be attained during the year.

The normal retirement age was 65 and 10 months in 2005. It will increase gradually to age 67 by 2027 for those who attained age 62 in 2022. By 2027, the full, actuarial reduction rates in benefits for those who retire at age 62 will increase to 30% from 24.5% in 2005.

All Social Security benefits are based on the primary insurance amount (PIA), which is derived in two steps. First, the worker's average indexed monthly earnings (AIME) is calculated by indexing the taxable earnings for each year from 1951 and later to the average wage level in the second year before age 62, disability, or death; summing indexed earnings and unindexed earnings in the years after age 60; and dividing the sum by the number of months elapsed after 1950 (or age 21, if later) through age 61 (or the year before the year of disability or death). Five years of the lowest earnings are dropped from the calculation of AIME (fewer dropout years apply to disabled workers). The benefit computation period is 35 years (fewer years apply to disabled workers).

Second, the PIA is then calculated on the basis of AIME. For people who retired at age 62 in 2005, the PIA was calculated as follows:

$$\begin{aligned}\text{PIA} = {} & 90\% \text{ of the first \$627 of AIME} \\ & + 32\% \text{ of the next \$3152 of AIME} \\ & + 15\% \text{ of AIME in excess of \$3779}\end{aligned}$$

The bend points ($627 and $3779) increase each year at the rate of increase in the average wage. Benefits for workers who retire earlier than the normal retirement age are subjected to actuarial reductions in the PIA – a 24.5% reduction for those who retired in 2005 at age 62 and pro rata reductions for those who retired at ages 63 and 64.

Each eligible auxiliary member of a retired worker is entitled to benefits equivalent to 50% of the PIA. But spouses who claim auxiliary benefits before age 65 face an actuarial reduction unless an eligible child is present. In addition, when spouses receive pensions that are based on their own federal, state, or local government work that is not covered by Social Security, their Social Security benefits are reduced by an amount equal to two-thirds of their public pensions. Total family benefits may not exceed the maximum family benefit, which ranges from 150% to 272% of the PIA, depending on the level of the PIA, with paradoxically the lowest percentage (150%) applying to the lowest range of AIME, that is, 0 to $801 in 2005.

Widows or widowers of insured workers are entitled to 100% of the PIA of their deceased spouse if they claim benefits at the normal retirement age or later. Widows and widowers can claim benefits as early as age 60 (or age 50 if disabled), although the benefits are subjected to actuarial reduction.

Children under age 18 (or under 19 if still in high school) and the surviving spouse who is caring for them are entitled to SI benefits. Each eligible survivor is entitled to benefits equal to 75% of the PIA, but the maximum family benefit rule applies. When the youngest child reaches age 18, benefits for the surviving spouse cease, but if any child has a disability that originated in childhood (before age 22), benefits for the child and caretaker parent continue without an age limit.

To receive DI benefits, a worker must be unable to engage in any substantial gainful activity (SGA) because of a severe physical or mental impairment that is expected to last for at least 12 months or to result in death. Education, work experience, and age are taken into account in determining disability. DI beneficiaries must accept rehabilitation services that are offered by state rehabilitation agencies if the Social Security Administration (SSA) determines that these services are likely to be successful.

Eligible disabled workers are entitled to monthly benefits equal to the PIA. Eligible children and the spouse caring for a child under age 18 or children who became disabled before age 22 are each entitled to 50% of the PIA. The total family benefits may not exceed the maximum family benefit.

Unless they recover medically from their disability, disabled people generally are allowed to continue to receive benefits for up to 9 months while they test their ability to work. Benefits are not terminated until the second month following the earliest month after the trial work period in which the individual engages in SGA or is determined by the SSA to be able to engage in SGA.

OASDI is financed by payroll taxes on employers, employees, and the self-employed. The payroll tax is authorized by the Federal Insurance Contribution Act up to the maximum taxable earnings ($94 200 in 2006). The tax rate of 6.2% for OASI and DI combined is levied on employees and employers, totaling 12.4% of the payroll. The self-employed pay at the 12.4% rate. Allocation of the payroll tax is as follows: 5.30% for OASI and 0.90% for DI.

Emerging Problems

Demographic Shifts

The major cause of the increasing difficulty in financing Social Security is demographic shifts in the US population. The old dependency ratio, defined as the ratio of the number of people aged 65 and older to the number of those aged 20 to 64, is rapidly increasing. The ratio is projected to increase from 0.203 in 2005 to 0.350 in 2030 and to 0.431 in 2080 (see **Table 1**). The trend toward higher old dependency ratios will continue even after the Baby Boom generation passes away because the proportion of children will continue to decline.

As **Table 2** shows, the number of OASI beneficiaries is projected to increase from 40 million in 2005 to 95 million in 2080 (or by 138%), and the number of DI beneficiaries is projected to increase from 8 million in 2005 to 15 million (or by 87%). As a result, the total number of the combined OASDI beneficiaries will increase from 48 million in 2005 to 111 million in 2080 (or by 129%). All told, the number of OASDI beneficiaries is projected to increase from 16% to 27% of the US population from 2005 to 2080.

The growing life expectancy at age 65 and the trend toward early retirement are increasing the duration of receipt of OASI benefits. In particular, life expectancy at age 65 increased from 14.0 years in 1980 to 16.2 years in 2004 for men and from 18.4 years in 1980 to 19.0 years in 2004 for women. The percentage of those who retired earlier than the normal retirement age increased from 58% in 1980 to 74% in 2003 for men and from 70% in 1980 to 77% in 2003 for women.

Actuarial Imbalance

The Social Security program is facing a great challenge to remain financially solvent. **Table 3** shows how much the annual income rate and cost rate will diverge in the future as a percentage of the payroll. During the next 25 years (2005–29), the OASI Trust Fund will be financially solvent; that is, annual income exceeds costs, but in the next 50 years (2005–54) and the next 75 years (2005–79), it will face actuarial imbalances equivalent to 0.87% of the

Table 1 The aged dependency ratio: 2005–80

Year	*Aged dependency ratio*
2005	0.203
2010	0.210
2020	0.271
2030	0.350
2040	0.373
2050	0.381
2060	0.401
2070	0.419
2080	0.431

Source: Board of Trustees, OASDI (2005), Table V.A2, p. 77.

Table 2 Projected numbers and proportions of OASDI beneficiaries: 2005–80

Year	*Number of beneficiaries under OASI*	*Number of beneficiaries under DI*	*Total number of beneficiaries under OASDI*	*Total beneficiaries as a percentage of the population*
2005	40 085	8260	48 345	16.0
2010	43 785	95O2	53 287	17.0
2020	57 876	10 971	68 847	20.4
2030	71 798	12 329	84 127	23.5
2040	78 266	13 035	91 301	24.5
2050	81 560	13 998	95 558	24.9
2060	86 141	14 503	100 644	25.5
2070	91 175	14 897	106 072	26.2
2080	95 464	15 416	110 880	26.7

Source: Board of Trustees, OASDI (2005), Tables V.C4 and V.C6, p. 111 and 118.
Note: Old-Age Insurance (OAI) beneficiaries include retired workers, spouses, and children. Survivors Insurance (SI) beneficiaries include widows/widowers, mothers/fathers, children, and parents. Disability Insurance (DI) beneficiaries include disabled workers, spouses, and children.

Table 3 Summarized Income rates and cost rates for valuation periods, by trust fund, under intermediate assumptions, calendar years 2005–79 (as a percentage of the taxable payroll)

Summarized periods	*OASI*			*DI*			*Combined*		
	Income rate	*Cost rate*	*Actuarial balance*	*Income rate*	*Cost rate*	*Actuarial balance*	*Income rate*	*Cost rate*	*Actuarial balance*
25 years: 2005–29	12.53	11.59	0.95	2.02	2.14	– 0.12	14.55	13.72	0.83
50 years: 2005–54	12.06	12.93	– 0.87	1.95	2.21	– 0.26	14.02	15.15	– 1.13
75 years: 2005–79	11.93	13.53	– 1.60	1.94	2.26	– 0.32	13.87	15.79	– 1.92

Source: Board of Trustees, OASDI (2005), Tables IV.V4, p. 56.

payroll and 1.60% of the payroll, respectively. This means that for the OASI to remain financially solvent until 2079, income has to increase by the amount equivalent to 1.60% of the payroll.

The DI program will face an even greater challenge. For the 25-year, 50-year, and 75-year periods, the DI Trust Fund will be actuarially imbalanced. For the 75-year horizon, the DI Trust Fund will face an actuarial imbalance equivalent to 0.32% of the payroll, which is considerably larger than the OASI's actuarial imbalance of 1.60% of the payroll, in relative terms.

The combined OASDI Trust Funds will be positively balanced during the 25-year period but will face an actual imbalance of 1.13% of the payroll and 1.92% of payroll during the 50-year and 75-year periods, respectively. The Board of Trustees' projection of the actuarial imbalance for the infinite time horizon will be 3.5% of the payroll, or $11.1 trillion (in present value), or 1.2% of the gross domestic product (GDP).

Taking into account the accumulated assets, which will peak in 2015 at a level equivalent to 469% of the annual expenditures for OASI and in 2005 at the level equivalent to 215% of annual expenditures for DI, the following scenario is projected to occur in the coming years. Starting in 2018, the OASI's outgo will exceed its income (excluding interest on the Trust Fund) – a situation that began in 2005 for the DI Trust Fund. For OASDI as a whole, the outgo will exceed income beginning in 2017. Thereafter, OASI and DI will have to redeem the accumulated interest to supplement the annual income, which are kept in the respective Trust Funds, to keep paying the scheduled benefits. But the accumulated interest will be exhausted in 2028 for OASI, 2014 for DI, and 2017 for the combined OASDI. After these years, OASI and DI will need to redeem the accumulated assets in their respective Trust Funds to supplement their annual income to keep paying the scheduled benefits. Such a condition will continue until 2043 for OASI, 2017 for DI, and 2041 for the combined OASDI programs. In other words, the OASI Trust Fund assets will be exhausted in 2043, the DI Trust Fund assets will be exhausted in 2027, and the combined OASDI Trust Fund assets will be exhausted in 2041. Annual income will be sufficient to finance only 74% of the scheduled annual benefits in 2041 and only 68% in 2079.

These projections are predicated on the assumption that the Federal Treasury will be able to pay back to the OASI and DI Trust Funds what it owes, plus interest, in special issue US government bonds. However, these borrowed funds have never been set aside and have been used to pay for the operation of

other ongoing programs. Therefore, the federal government will have to come up with 'new money' to make it possible for the OASDI Trust Funds to redeem the special issue bonds, plus interest.

Furthermore, the OASDI Trust Funds will need additional income equivalent to 1.92% of the payroll, which is referred to as unfunded liabilities, to pay the scheduled benefits until 2079. To do so, the federal government will need to come up with financial resources in addition to what it has borrowed from the OASDI Trust Funds, plus interest. In short, the real financial struggle will start in 2018 for OASI and started in 2005 for DI, when their annual incomes become less than the annual outgo.

To make sense of the income rate, cost rate, accumulated assets, and unfunded liabilities, the evaluation of OASDI's financial conditions based on the GDP is instructive. **Table 4** shows that the cost of the combined OASDI is projected to increase 50% from 4.26% of the GDP in 2005 to 6.39% of the GDP in 2080, but the income is expected to be stable: 4.82% of the GDP in 2005 and 4.46% in 2080. As a result, the balance will change from +0.56% of the GDP to –1.93% of the GDP (or by 345%) during this period.

With regard to the income, cost, and balance for the 25-year, 50-year, and 75-year periods, the combined OASDI's balance will be +0.31% of the GDP during the 25-year period, –0.42% during the 50-year period, and –0.70% during the 75-year period. The progressively worsening financial problem signals that the earlier that policy initiatives are taken, the easier the financial problem can be solved.

The basic problem is that no matter where the funds come from (annual income, fund assets, or general revenues), the United States will need to spend as much as 6.39% of its GDP to pay for OASDI in 2080, compared with 4.26% of its GDP in 2005. Thus, the basic question that confronts the nation is whether it is willing to spend an increasing proportion of the US GDP for OASDI. On the basis of the initiatives taken by the current and previous administrations to find solutions to make the financing of the OASDI more manageable, it seems clear that the United States is searching for solutions to make the scope of the OASDI smaller.

Table 4 OASDI income, cost, and balance in selected years and in summarized periods: 2005-80 (as a percentage of GDP)

Year	*Income*	*Cost*	*Balance*
2005	4.82	4.26	0.56
2010	4.86	4.28	0.57
2020	4.86	5.24	−0.38
2030	4.83	6.14	−1.31
2040	4.76	6.31	−1.54
2050	4.69	6.24	−1.55
2060	4.61	6.29	−1.67
2070	4.54	6.36	−1.82
2080	4.46	6.39	−1.93
Summarized periods			
25 years: 2005–29	5.47	5.16	0.31
50 years: 2005–54	5.17	5.59	−0.42
75-years: 2005–79	5.04	5.74	−0.70

Source: Board of Trustees, OASDI (2005), Table IV.F4, p. 171.

Other Problems

The Issue of Money's Worth Since later cohorts of workers have been taxed at increasingly higher payroll tax rates, the OASI program has become less effective in providing an adequate return on workers' contributions to the program. C. Eugene Steuerle and Jon M. Bakuja showed that the average-wage, single man who retired in 1960 received $36 500 (in constant dollars) more in retirement benefits during his lifetime than what he paid into the OASI program, whereas his counterpart who will retire in 2030 is expected to receive lifetime benefits that are $56 200 less than his lifetime contributions.

The situation of minority groups poses a different kind of problem. Because Black workers generally receive lower wages during their lifetime, their monthly benefits tend to be higher relative to their AIME than those of White workers. However, on the basis of their lifetime contributions and lifetime benefits, the ratio of their lifetime benefits to lifetime contributions is lower than that of White workers, primarily because they tend to die younger.

One-Earner Couples versus Two-Earner Couples Under the current system, one-earner couples with the identical maximum AIME as that of two-earner couples, with each spouse earning half the maximum, receive larger benefits when they both are alive than when only one is alive.

Table 5 illustrates the situation of one-earner couples and two-earner couples who retire at age 65 in 2004. While they both are alive, the benefit for

Table 5 Monthly benefits for one-earner couples with the maximum average indexed monthly earnings ($5892) and two-earner couples with half that amount ($2946): couples claiming benefits at age 65 in 2004

	One-earner couple	*Two-earner couple*
Benefit when both spouses are alive	$2798	$2596
Benefit when only one spouse is alive	$1865	$1298

Source: Board of Trustees (2004), p. 100; Mercer (2003), pp. 3.
Note: Couples are assumed to be the same age and to retire at age 65.

the one-earner couple is the maximum benefit plus one-half that amount, and the benefit for the two-earner couple is the sum of two identical benefits, with each based on half the maximum AIME. Obviously, 1-1/2 of the maximum benefit is higher than the sum of the two benefits, despite the progressive benefit formula that is applied to low-wage workers. Moreover, the surviving spouse of the one-earner couple receives the maximum benefit, whereas the surviving spouse of the two-earner couple continues to receive the benefit based on his or her own work record.

Research has shown that the probability of a non-working spouse receiving the full spousal benefit is higher among the higher-income classes than among the lower-income classes. The same applied to spouses who received dual benefits. (These benefits represent the partial spousal benefits when spouses' benefits are lower than the half the benefits of the primary beneficiary.) The dual benefit equals half the benefit of the primary beneficiary minus the benefit amount of the spouse based on his or her own work record. Thus, the benefit for the dual beneficiary equals half of the benefit of the primary beneficiary – the same as the benefit for spouses who never worked.

Reform Initiatives and Proposals

The 1983 Amendments to the Social Security Act

The 1983 Amendments to the Social Security Act was the second serious attempt to meet the impending deficit in the trust funds. The major changes were to increase revenue, to decrease benefits, and to reduce the rate of retirement. To increase revenue, previously excluded groups of workers (newly hired federal employees and all members of Congress, employees of non-profit organizations, and some local and state governmental employees) were covered. To decrease benefits, the timing of cost-of-living increases was delayed; a portion of the Social Security benefits of those who had incomes in excess of $25 000, if individuals, and in excess of $32 000, if married, was subjected to income tax; and a different benefit formula was established for governmental employees who became eligible for both civil service pensions and Social Security benefits, in order to prevent them from taking advantage of the progressive benefit formula in calculating PIA under OASI. To reduce the rate of retirement, the normal retirement age (which was 65 years) was increased to gradually reach 67 in 2022.

Perhaps the most important policy initiative in the 1983 Amendments was to increase the tax rate so that a sizable amount of assets would be accumulated in the Trust Fund to pay for the increasing cost of OASI when the Baby Boom generation retires. These accumulated assets have been instrumental in prolonging the year of actuarial exhaustion but are not a permanent solution to maintaining the solvency of OASI.

The 1994–96 Advisory Council on Social Security

To shore up the financial health of OASI, the Clinton administration established an advisory council on Social Security to find viable, alternative solutions to make OASI financially solvent permanently. The council recommended three alternative approaches: the Maintain Benefits (MB) plan, Individual Accounts (IA) plan, and Personal Security Accounts (PSA) plan. Cutting across these three recommendations was the goal not only of establishing a permanent actuarial balance but also of increasing the money's worth ratios for younger generations. Furthermore, all plans recommended that part of Social Security contributions be placed in the equity market.

Under the MB plan, as much of the status quo as possible was to be maintained. The specific reform agenda included extending Social Security coverage to all state and local government workers, using three more years to calculate AIME, and increasing the OASDI payroll tax rate by 0.8% for both employees and employers.

The IA plan incorporated some of the same approaches of the MB plan. In addition, it included more aggressive strategies to make OASDI financially solvent: reducing the second and third multiplying factors from 0.32 and 0.15 to 0.224 and 0.105, respectively, in calculating the PIA; accelerating the increase in the normal retirement age, so it would reach 67 in 2011, after which it would increase automatically according to the increase in life expectancy; reducing the surviving spouse's and aged spouse's benefits as a percentage of the PIA; and, most important, requiring all workers to contribute an extra 1.6% of taxable earnings to establish their own individual retirement accounts (IRAs).

The PSA plan includes the most radical strategies to shore up the financial health of OASI, placing the establishment of personal security accounts as a centerpiece of the reform agenda. The plan would require five percentage points of the OASDI employee payroll taxes to be carved out to enable workers to develop their own PSAs and to change the traditional Social Security benefits, which are based on AIME, to a flat amount benefit. In essence, then, the PSA plan envisions a double-decker scheme for the future Social Security system: the first tier (flat benefits) and

the second tier (a defined-contributions plan). It anticipates the need for additional funds to pay for the transition cost, which would be paid back with interest by 2070.

President's Commission to Strengthen Social Security

This commission was established by the Bush administration. It recommended three alternative plans: Model 1, Model 2, and Model 3. All models incorporate some form of personal retirement accounts (PRAs). Of the three models, Model 2 is the most comprehensive and aggressive in achieving the goal: permanent solvency of OASI.

Model 2 would establish voluntary PRAs by carving out four percentage points of workers' payroll taxes, up to $1000 annually. The cap was meant to make the contribution progressive in favor of low-wage earners. The traditional Social Security benefits would be offset by the workers' PRA contributions, which would be compounded at an interest rate of 2% above inflation. The combined benefits from PRAs and the traditional Social Security program are expected to be greater than the benefits that would be received by those who do not establish PRAs and than the future benefits payable under the current system if it is not reformed.

While Model 2 shifts much of the responsibility for ensuring future retirement benefits from the government to individuals, it also attempts to ensure that long-term low-wage workers would be guaranteed to have above-poverty-line benefits through the traditional Social Security program. The plan recommends that 30-year minimum-wage workers would receive benefits equivalent to 120% of the poverty line. Additional protection for such workers' survivors would be provided as well. Furthermore, to reduce the future traditional Social Security benefits, Model 2 recommends that earnings during working lives would be price indexed instead of wage indexed.

If all these recommendations are implemented, the commission expects that a medium earner who chooses to establish a PRA and retires in 2051 would receive combined benefits that would be 59% higher than the benefits that are paid to today's retirees. At the end of the 75-year period (2079), the PRA system will hold $12.3 trillion (or $1.3 trillion in today's dollars and discounted to the present value). Also, if all these steps are taken, the commission anticipates a positive cash flow by 2079. It should be noted that this plan requires a temporary transfer from general revenue to keep the Trust Fund solvent between 2025 and 2054.

There will be sizable between-cohort variations in the rates of return on the contributions that are made to PRA, as Gary Burtless argued. However, Martin S. Feldstein argued that because the rates of return on contributions would be so high, compared with the rates of return on the contributions to the traditional Social Security program, it is probable that every participant in the PRA plan would be better off than those who are not.

By far the most radical change that the commission recommended is the adoption of price indexing of earnings in prior years in calculating the AIME, which is the basis for calculating the PIA. Under the current system, wages earned in early years (since 1951 or at age 21, whichever is later) are adjusted to account for the rate of increases in average wages. For example, the index factor for earnings made in 1951 is 11.9 to make it equivalent to the earnings made in 2002. To adjust the 1951 earnings for inflation to the 2002 price level, one needs to use the index factor of only 9.9. Thus, the use of the price index, instead of the wage index, would result in lower AIMEs, which would lead to lower Social Security benefits. The commission claimed that the adoption of wage indexing alone would not only help eliminate all unfunded liabilities, but would ensure permanent financial solvency of OASDI.

It is important to note that price indexing would result in the same level of constant purchasing power in Social Security benefits across cohorts, whereas wage indexing would guarantee the same replacement rates of Social Security benefits, which would have a built-in growth in Social Security benefits in later cohorts. It is obvious that Social Security benefits that are based on price indexing of earnings in prior years would be considerably easier to finance than such benefits based on wage indexing.

Some may be concerned about the declining replacement rate envisioned by the commission. However, because there are numerous private retirement plans, such as IRAs, 401(k) plans, and Keogh plans, the replacement rates involving Model 2 plus all these private plans would provide relatively high replacement rates in the future.

The commission stated that the PRA program not only would be effective in establishing individually funded accounts that will be under the control of the participants, but also would increase the national savings. The first part is obvious; the second part may or may not be true because the current system, which is based on pay-as-you-go financing, is not contributing to the national savings. As was reviewed, Model 2 maintains some of the same features that are included in the current system.

Resistance to Radical Changes in Social Security

While the movement toward radical change in Social Security is gradually taking hold in the United States, reviewing the various recommendations to reform Social Security reveals that there is no national consensus on how to reform it. Therefore, the implementation of Model 2, as recommended by the President's Commission to Strengthen Social Security, will not be easy. The sources of resistance are (1) an alternative approach to reform Social Security and (2) persistently strong, positive attitudes toward Social Security.

Alternative Approach An alternative approach to Social Security reform attempts to keep the basic structure of the Social Security program as intact as possible. The plan, recommended by Robert M. Ball, a former commissioner of Social Security who served under Presidents Kennedy, Johnson, and Nixon, exemplifies such an approach. The steps that he recommends include increasing the taxable payrolls, the infusion of general revenue by taxing estates, the extension of coverage to those who are not covered, the investment of the trust funds' assets in the equity market, and the reduction of cost-of-living increases in benefits. These steps, Ball believes, will eliminate the deficit without changing the Social Security program structurally.

Specifically, his plan would attempt to eliminate the deficit (which is 1.9% of the payroll) in the following ways: (1) restoring the 90% maximum taxable payroll from the current 83%, which would reduce the deficit by 0.6%, thus reducing the deficit to 1.3%; (2) earmarking all the revenue from the estate tax that will be imposed on estates in excess of the exempt amount (which will reach $3.5 million for individuals and $7 million for a couple in 2009), which would reduce the deficit by 0.5%, bringing the deficit down to 0.8%; (3) investing 20% of the accumulated Social Security trust funds in the equity market, which would further reduce the deficit by 0.4%, thus bringing the deficit down to 0.4%; (4) extending Social Security coverage to all newly hired state and local government employees, which would reduce the deficit by 0.2%, thus bringing the deficit down to 0.2%; and (5) adopting a lower rate of cost-of-living adjustments, which would reduce the deficit by 0.4%, thus turning the deficit into a positive accumulation of trust funds. In addition, Ball advocates that temporary increases in the payroll tax should be considered when short-term estimates show that the trust funds would begin to decline within the next 5 years.

Ball contends that if all these steps are taken, not only will there be no need to cut benefits, but also the Social Security system will be able to meet the shortfall in the trust funds for the coming 75 years and beyond. He concludes that if these steps are taken, the United States can deal with the financial challenge effectively, and there is no financial crisis in Social Security.

Ball's recommendations are predicated upon his conviction that the American public needs an ultimate safety net in old age and that the Social Security program is the most effective vehicle to achieve this objective. He further argues that Social Security benefits constitute an earned right and hence cannot be cut or taken away.

The Ball plan is specific and seems feasible in terms of maintaining a level of trust funds that is large enough to keep paying the promised benefits to current and future beneficiaries. However, because the Social Security program will still be largely unfunded because the federal government continues to spend the assets that are accumulated in the trust funds to finance ongoing government programs (and the federal government will continue to have deficit budget for many years to come), the question is whether the federal government can redeem the special issues (that is, bonds held by the Social Security trust funds) when that time comes, which is approaching rapidly. Such an uncertainty exists, despite the long-held principle of the full faith and credit of the United States to protect the Social Security contributions that have been made in the past.

Public Opinion The public sentiment toward structural changes seems to be not strong enough for the United States to reform Social Security radically, as advocated by Model 2, which was developed by the President's Commission to Strengthen Social Security. The public's resistance to such a radical reform was substantiated by a recent study by Fay Lomax Cook and Lawrence R. Jacobs, which investigated the outcomes of public opinion surveys regarding Social Security over the past 25 years and also findings of several recent surveys regarding specific questions related to changes in Social Security provisions. Cox and Jacobs observed that the level of public support for Social Security has been high and stable, indicated by the fact that 89 to 95% of the public think that the Social Security expenditures are too little or just about right. Furthermore, they observed that the majority of the public prefer an incremental reform instead of a radical reform; that the public prefers an increase in the Social Security tax instead of benefit cuts; and that if benefits must be cut, only benefits of rich beneficiaries should be cut (58%). Finally, when risks are considered, the majority (51%) of the public oppose the privatization of Social Security, with 44% favoring it and 5% having no opinion. These public opinions seem to be contrary to what Model 2 proposes to do.

US Income Support for the Elderly in Perspective: A Comparison to Other Countries

Due to the intense national debate that was forged by the Bush administration and the media blitz that has accompanied it, some among the public have come to believe that there is a coming crisis in financing Social Security when the Baby Boomers retire that the nation needs to prepare for. However, the gravity of the problem needs to be assessed with some degree of rationality. Comparing the scope of financial support for the aged population in the United States with that of other industrialized countries can place the US situation in perspective. **Figures 1**, **2**, and **3**, which were created using the Organisation for Economic Co-operation and Development (OECD) Social Expenditure Database, illustrate how much (or how little) the United States is providing in cash payments to the elderly (including both social insurance and income-tested benefits) in comparison to Japan, Germany, and Sweden.

It is clear that the United States, along with Japan, has a small welfare state, measured by the percentage of the GDP that is used for all social welfare programs (see **Figure 1**), and that compared with other countries, the percentage of the US GDP that is used to provide cash payments for the elderly is small (see **Figure 2**). Since 1997, the United States has spent the lowest percentage of its GNP on cash payments. Partly because of the small size of the US welfare state, the spending on cash payments constitutes a large percentage of the total social welfare expenditure, second only to Japan's (see **Figure 3**).

These figures indicate that there still is room for the United States to expand income transfer programs for the elderly, of which Social Security is a large part. A more important challenge facing the United States is of a different kind. As the United States expands public spending for income transfer programs for the elderly, the country will face the squeezing effect to the detriment of the non-aged population, especially children, unless it is willing to expand the size of its welfare state. **Figure 3** indicates that in 1998, 34.5% of the total social welfare expenditures was dedicated to providing cash payments to the elderly, second only to Japan, which allocated 37.7% of its total social welfare expenditures for this purpose. Therefore, there is not much left in the US federal budget to pay for programs for children and other sectors of the population. The situation will become worse as the United States spends more for cash payments for the elderly in coming years. The situation will be untenable if one takes into account the rapidly growing spending for Medicare and Medicaid, both of which are mostly targeted to the elderly population.

Partly because of the neglect of the child population, the income status of children, relative to that of

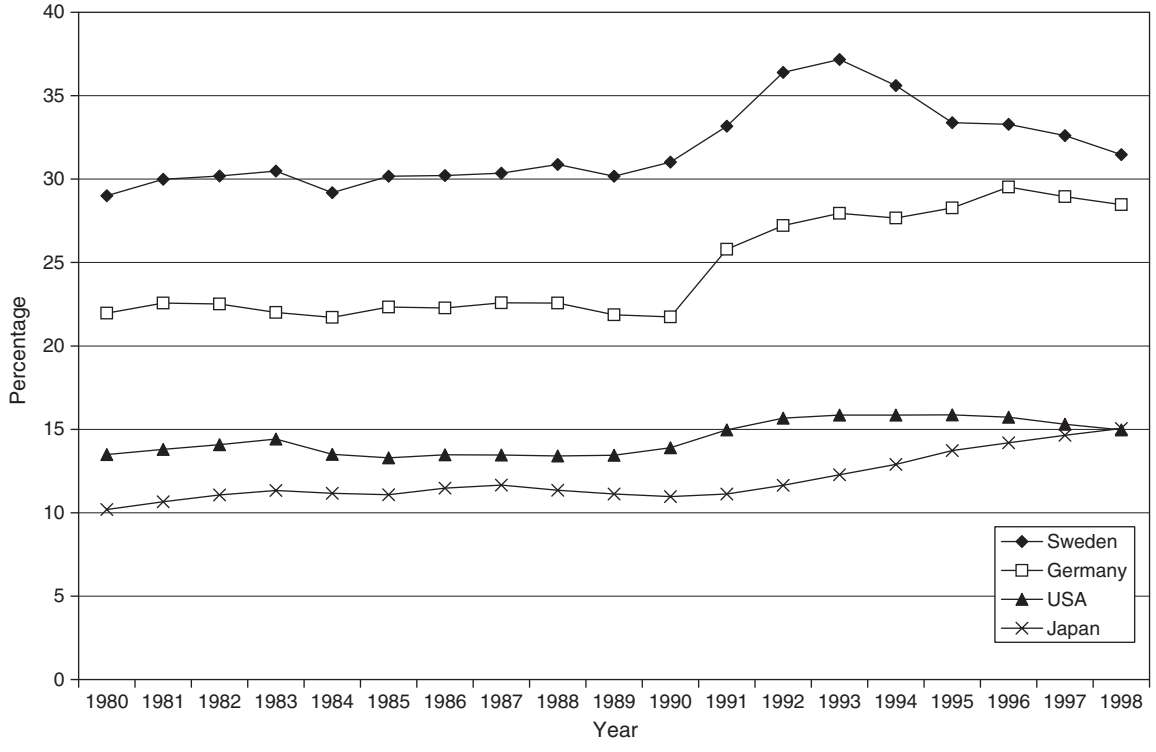

Figure 1 Total social welfare expenditures, 1980–98 (percentage of the GDP).

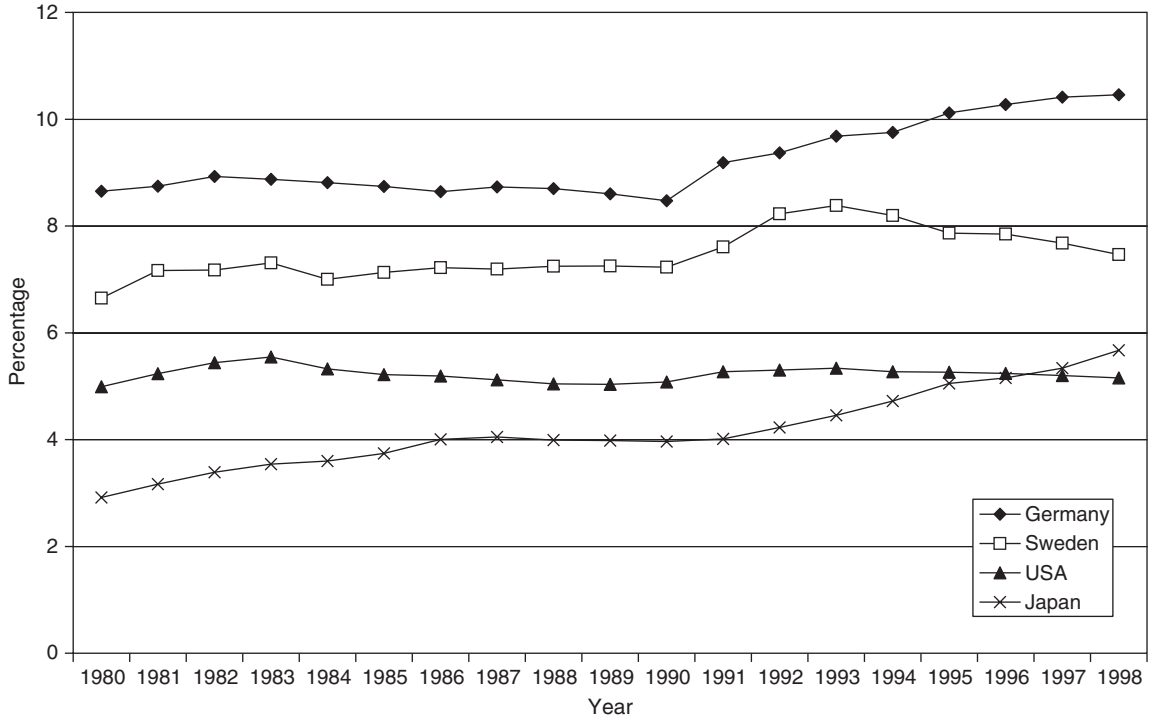

Figure 2 Cash benefits for the elderly, 1980–98 (percentage of the GDP).

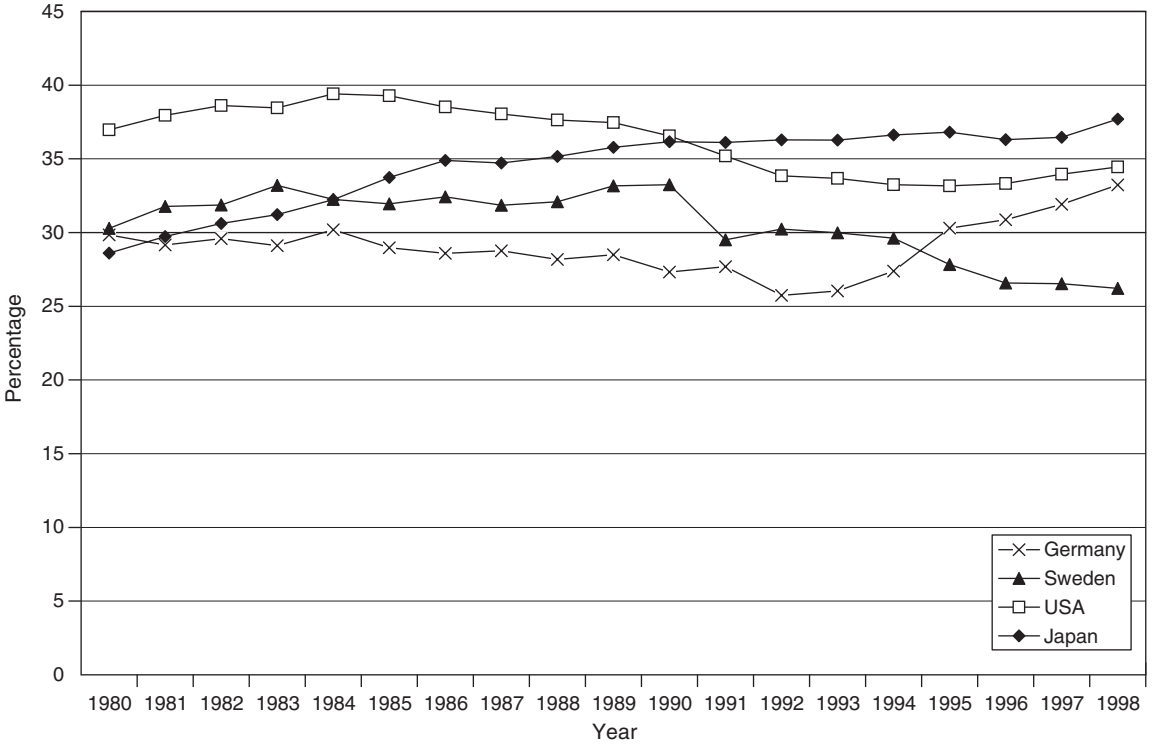

Figure 3 Cash benefits for the elderly relative to total social welfare expenditures, 1980–98 (percentage).

elderly people, has deteriorated in recent decades. Research has shown that children's income status (measured by the income-to-needs ratio) declined from 101.2% in 1969 to 98.9% in 1979 and to 85.5% in 1989 of that of the elderly in the respective years.

Obviously, Model 2 of the President's Commission to Strengthen Social Security would contribute to

balancing the nation's commitment to supporting the young segments of the population as the nation undergoes Social Security reform. Model 2 suggests that a considerable part of Social Security should be individually funded so that the public financing of Social Security would be smaller than otherwise. As a result, the government would prevent the squeezing effect of the expanding Social Security system and, hence, would have greater public financial resources available to fund programs for the non-aged population, particularly the population of children.

See also: Demography; Economics: Society; Politics of Aging; Retirement.

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Speech and Communication (speech styles)

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Glossary

Elderspeak – A speech style often employed when addressing elderly adults; speech characteristics may include slower speech rate; exaggerated intonation and increased loudness and pitch; simplified vocabulary, semantics, and grammar; frequent repetition; and the use of diminutives (e.g., sweetie, dearie). Non-verbal expressions accompanying the verbal features may include winking, eyebrow raising, rolling eyes, and sighing. Such accommodations appear to be evoked by perceptions of

physical, cognitive, and/or communicative declines associated with aging and/or dementia. Other terms for elderspeak are secondary baby talk, dependency-supporting communication, and patronizing talk. The first two terms reflect speech traits that one may adopt in addressing infants and other individuals who are (perceived to be) dependent on a caregiver, while the latter term refers to the reaction of older adult recipients to such inappropriate talk. The use of some aspects of elderspeak (e.g., slow speech rate, exaggerated pitch) may create affective barriers and lead to poor communication between older and younger adults, whereas other aspects (e.g., semantic elaboration, less complex sentences) appear to facilitate intergenerational communication because they accommodate to age-related changes in language processing abilities.

Speech – The production of language via the vocal tract or manually for the purpose of communicating a message to another person.

Speech Accommodations – An attempt on the part of one communicator to adapt his or her speech to another communicator based on beliefs and perceptions of that communicator's personal characteristics and social identity. Accommodations serve the purpose of promoting convergence (identifying with) or divergence (distancing from) between communicators. Communicators may underestimate the perceived communication abilities of their interlocutor and speak in a way that is overaccommodating. They may alternatively overestimate their interlocutor's competence, or ignore their needs and engage in underaccommodating speech.

Speech Style – A profile of speech characteristics that show systematic differences from other profiles. The dimensions in which speech styles vary include pronunciation and prosody, choice of vocabulary, and grammatical and discourse features. Speech styles can be associated with particular social groups (e.g., younger vs. older adults, males vs. females), yet the same individual may draw from a repertoire of speech styles, with the use of each dependent on personal characteristics of the interlocutors (e.g., age, appearance, gender, familiarity, social status, ethnic identity) and contextual variables (e.g., topic, purpose of the interaction, formal vs. informal setting).

Stereotype – Perceptions of individuals associated with a particular group based on perceived attributes of that group as a social category (e.g., older people are wise). Stereotypes can be positive or negative, and they play an important role in, and are a reflection of, the social construction of aging.

Introduction

Speech styles are constructed through a complex interplay of diachronic (historical) and synchronic (current) sociocultural forces. Diachronically, language is passed on in a seamless fashion between generations, thereby facilitating communication between generations; however, such transmission does not preclude subtle changes to speech and language, nor more conspicuous sociolinguistic changes over time. For example, in addition to the new words that are coined each generation, old words often take on new meaning across generations (e.g., cool, hot), and speech habits pertaining to certain linguistic forms change from generation to generation (e.g., the off- and on-again generic use of male pronouns across the past few centuries and generations). The usage patterns of these and other forms vary and evolve depending on the speakers involved (e.g., younger vs. older adults), topic of conversation (e.g., politics vs. travel), and context of interaction (e.g., formal vs. informal). In conjunction with these historical changes are synchronic forces, most notably human developmental processes and sociocultural values, beliefs, and practices that find expression in and help differentiate the speech styles of different social groups. For example, the salience of emotion regulation in forming and maintaining interpersonal relationships appears to increase for older adults (according to socioemotional selectivity theory). This change has been attributed in part to adults' perceptions of how much time they have left in life and the increased importance of selecting social partners based on the meaningfulness of a relationship. In contrast to younger adults' more objective fact-finding-relaying orientation, older adults engage more in interpretive and subjective reflections during conversation. These different orientations and conversational goals can lead to age-based preferences for communication partners and, ultimately, to different ways of communicating (speech styles) for and with each age group. Over the course of human development, sociocultural forces serve to create and perpetuate intergenerational differences in age identity and communication style. These include perceptions of and access to roles, power, status, mobility, and vitality, all of which tend to decline in older age relative to middle age and contribute to variations in younger and older adults' speech styles (*see* Generational Differences: Age-Period-Cohort).

In this article, the speech styles most relevant to aging are described and discussed, beginning with an overview of the changes in speech associated with aging. Speech styles in intergenerational interactions are examined from the perspectives of their origins, characteristics, consequences, and cultural variations. The ways in which speech styles are realized in communication between younger and older adults are accounted for by drawing upon principles and models based in communication accommodation theory. The article concludes with suggestions for promoting positive intergenerational communication.

Prior to addressing the speech styles of different age groups, it is first necessary to delineate what ages are encompassed by different age grouping labels (e.g., older adult and younger adult). Traditionally, the classification of older or elderly has been applied to adults age 65 and older and that of younger to those 30 years or younger, with middle-aged falling somewhere in between. In response to the increase in longevity over the past century, a new division of age groupings has emerged between the young-old (65–75) and the old-old (85 and older). In addition, it appears that how adults at different ages classify age groupings shifts as one gets older (i.e., moving boundaries upward). For the purposes of this article, however, the traditional distinction between younger, middle-aged, and older adults will be followed. When referring to younger adult speech addressed to older adults, middle-aged adults are included with the younger adults since some research has shown that both groups engage in a similar speech style when addressing older adults.

Age as a variable is non-negotiable in the sense that we cannot change our age, although some may seek to modify how their age is perceived by others through use of makeup, exercise, diet, social networks, etc. On the other hand, age is negotiable in the sense of age groupings because the boundaries between groupings are fuzzy, and perceptions of age categories vary depending on the age and prototypicality of the respondent. That is, the greater the distance a person is perceived to be from age-grouping boundaries, or the more typical he or she is of a group, the easier it is to render an age-based categorization. The latter can have a significant influence on the nature of communication accommodations observed between individuals of different ages.

Speech Characteristics of Older Adults

Developmental factors, in addition to those mentioned previously, that contribute to different speech styles across the life span include age-related changes in physical (motor, sensory) and cognitive (e.g., language, speed of information processing, memory) attributes. As people age, changes take place in motor functions related to speech, sensory functions of hearing and vision, and cognitive and linguistic functions, all of which may serve as cues in recognizing and defining the speech of older adults (*see* Markers of Aging).

Due to anatomical and physiological changes in aging, including atrophy of muscle tissue, increase in stiffness in the vocal folds, and cartilage degeneration, an older adult's voice may present with jitter and shimmer. Speech rate typically slows down due to both motor and cognitive declines in processing. The fundamental frequency (or pitch) of older adults' speech evolves across the life span and differs for males and females. Whereas male pitch is usually high-low-high over the three life span periods, females tend to present with a high-high-low pitch pattern. Change in amplitude appears to be a more salient perceptual feature of older adult males than change in pitch. Dentures or other orthodontic work may result in additional alterations to articulation and reduced intelligibility. Because of these anatomical and physiological changes, older adults may expend more effort when speaking, which may leave less energy for other levels of processing (e.g., grammatical structure).

Research on younger adults' identification and perception of older adults' voices has shown that older adults can be readily identified based on vocal cues. Moreover, the sound of an older person's voice is associated with negative evaluative responses by younger adults (e.g., an older adult will have a more difficult time understanding). Age-related changes in hearing (presbycusis) and vision (presbyopia) can affect older adults' awareness of their own speech qualities and their ability to benefit from visible speech cues of interlocutors. The consequences of sensory declines on speech production and perception may limit the older adult's desire and/or opportunities for communication and may serve to activate age-based stereotypes (*see* Hearing; Vision).

As mentioned previously, reduced efficiency in motor and sensory processing in aging can have implications for higher level processing such as language. In fact, some research has demonstrated that declines in cognitive and linguistic processing that have previously been attributed to cognitive aging may be largely accounted for by lower level perceptual constraints. Keeping the latter in mind, age-related changes in language production include an increase in word-finding problems, more dysfluencies, a tendency to reminisce (perhaps related to less accessible recent memories relative to remote

memories), a decrease in syntactic complexity and propositional density, and slower delivery (often attributed to declines in working memory and/or speed of processing). These linguistic changes may be exacerbated in demanding contexts and/or by the presence of an age-related neuropathological condition such as Alzheimer's disease or aphasia. On the upbeat side, older adults show gains in vocabulary, narrative and social skills, and world knowledge and experience compared to younger adults. Both the negative and positive changes to language and cognition influence the speech style of older adults, and in turn, younger adults' perceptions of aging and the speech accommodations they make when interacting with older adults (*see* Dementia: Alzheimer's; Information Processing/Cognition; Language and Communication in Aging; Language Disorders: Aphasia).

Speech of Younger Adults Addressing Older Adults

A considerable body of research literature has accumulated over the past two decades documenting the predominant characteristics of younger adults' speech addressed to older adults. The evidence attests to intergenerational differences in speech styles, in particular, how younger (vs. older) adults accommodate their speech to older adult interlocutors. Speech of younger adults to older adults depends in large part on the perceived competence, appearance, and communication behaviors of older adults, as well as on the values, beliefs, and attitudes about aging held by society. Positive perceptions of aging include viewing older adults as wise, good listeners and storytellers, empathic, generous, family oriented, supportive, and sincere. Negative perceptions include older adults as complaining, disapproving, overprotective, closed minded, and physically and/or cognitively on the decline. Such perceptions, or stereotypes, can be held implicitly and/or explicitly.

Although both positive and negative stereotypes of aging exist, research indicates that negative stereotypes are more prevalent and accessible than positive ones. Moreover, negative stereotypes appear to have greater effects on intergenerational communication than positive stereotypes. Negative stereotypes often lead to intergroup over- and underaccommodations in communication, which can adversely affect the quality of communication between younger and older adults. Overaccommodating speech to older adults, commonly referred to as elderspeak, is characterized by a number of simplifications to and exaggerations of normal speech. Most notable are reductions in grammatical and semantic complexity, exaggerated prosody and repetitiveness, and the use of diminutives (*see* Ageism and Discrimination).

As a speech style, elderspeak should not be thought of as exclusive or invariable in the sense that younger adults always (and only) use it when speaking with all older adults. Rather, it is a style that may be triggered by certain personal and contextual cues associated with the target interlocutor (e.g., appearance, body movement, voice quality, gender, cognitive and communication ability, topic/content of conversation, relationship of persons, and setting) and negative stereotypes related to these cues. Hence elderspeak is more likely to surface when interacting with an individual who exhibits more of the following characteristics: looks, sounds, and moves like an older person; is in a care facility; and has hearing, vision, and communication problems. On the other hand, just one salient aging cue, such as hearing loss, may be sufficient to elicit the use of elderspeak by a younger interlocutor. In fact, younger adults have been found to modify their speech to community-dwelling adults even when the older adult gives no indication of difficulty in comprehending or is otherwise portrayed positively.

The use of elderspeak by younger adults may be motivated by good intentions to accommodate to the perceived needs of the interlocutor (a compensating dimension of elderspeak); moreover, its use may often be out of the awareness of the speaker and be driven more by implicitly than consciously held stereotypes of aging. Nevertheless, because perceptions of aging are strongly associated with negative stereotypes, adjustments to speech and language by younger adults may be inappropriate for a particular older adult, in which case their communication behavior is said to be overaccommodating. On the other hand, elderspeak may be used instrumentally to control or gain the cooperation of others. For example, in long-term care settings, there is a power differential between staff and residents that may lead to interpersonal conflict when staff try to get residents to comply with requests. To mitigate or cover up the potential negative effects of this power imbalance, staff may use elderspeak because of its caring and nurturing dimension (*see* Caregiving and Caring; Long Term Care).

Experimental research has shown that some aspects of elderspeak (e.g., reduced syntactic complexity, semantic elaboration) may facilitate communication between younger and older adults, with and without dementia, whereas other aspects do not (e.g., exaggerated prosody, slower speech). The latter may also lead to negative perceptions of communication by older adults, loss of self-esteem, reduced social

interaction, and the reinforcement of age-based stereotypes. A further consequence of the use of elderspeak is that it limits older adults' exposure to more complex linguistic forms and thereby threatens the maintenance of their existing communicative competence. For these reasons, it is important to consider the appropriateness and effectiveness of elderspeak on an individual basis within a particular sociocultural context.

Evaluations by healthy older adults of the use of elderspeak are typically negative, with most viewing it as patronizing. Older adults' responses to younger adults who use elderspeak may be assertive or more passive depending on the context and interlocutors' roles and status. Responses that are extreme (e.g., very assertive or passive) may reinforce negative stereotypes of the older adult as irascible or incompetent and, consequently, perpetuate younger adults' use of elderspeak. More moderate responses, and the use of humor, may be more successful at subverting the use of elderspeak since they uphold the face of the recipient while maintaining the competence of the older adult.

Elderspeak appears to be perceived more favorably by older adults who are physically and/or cognitively frail. Some researchers have attributed this finding to the nurturing and positive affect that certain elderspeak characteristics convey (e.g., use of diminutives between intimates). Others, however, suggest that positive reactions to elderspeak by frail older adults, typically residing in institutions, may simply reflect (1) the habitual use of elderspeak as an institutional register, (2) learned helplessness, and/or (3) the residents' desire for any social contact even if it is demeaning. Sensitivity to appropriate use of speech accommodations is of particular importance when communicating with vulnerable populations such as individuals with dementia, who experience cognitive declines that can accentuate age-related cues and elicit more extreme forms of elderspeak. In addition, persons with dementia may not always be able to clearly indicate preferences for how others address them. Thus, interlocutors need to develop heightened awareness of their own accommodations and the recipient's verbal and non-verbal responses in an effort to support and maintain the individual's dignity and positive construction of self.

Older adults are more likely than younger adults to hold positive stereotypes of aging. For example, aging cues that elicit negative evaluations by younger adults, such as painful self-disclosures, are viewed more positively by older adults. They also seem to have more complex cognitive schemas of aging, which may contribute to the use of more person-centered communication behaviors. On the other hand, older adults also hold negative stereotypes of aging, but the impact of these on communication behavior appears to be different compared to younger adults. That is, older adults addressing other older adults are less likely to endorse the use of patronizing speech, although they may still be perceived as non-accommodating. Nonetheless, older adults may self-stereotype in negative (or positive) ways, and this may have consequences on their cognitive, emotional, physical, and social well-being. It may also lead them to make ageist comments even when talking with others in their age group.

Speech of Older Adults Addressing Younger Adults

Compared to the extensive literature on elderspeak, relatively little research has explored characteristics of older adults' speech when talking with younger adults. Some research reports that older adults hold negative stereotypes about communication with younger adults. For instance, although older adults may perceive younger people as being more open than older people, they also view younger adults as more irresponsible, reckless, naive, self-centered, arrogant, and/or lacking in communication skills. These stereotypes may manifest in underaccommodating speech to younger adults. For example, younger adults report that older adults are less attentive and more verbose in conversation, and their speech is overly protective, disapproving, closed-minded, and complaining. On the other hand, some positive (and in some cases, contradictory) perceptions of older adults' speech and communication portray older adults as good story tellers and patient listeners. As mentioned earlier, these contrasting views may be attributed to variability in younger adults' experiences with older adults.

Older adults' speech addressed to younger (and older) adults has been found to be simplified relative to younger adults' intragroup speech. This suggests that older adults do not accommodate their speech to the preferred level of complexity of younger interlocutors (e.g., faster speech rate). Similar to the case of younger adults' use of elderspeak, older adults' under- or non-accommodating communicative approach to younger adults should not be presumed intentional. Nevertheless, when older adults do not take into account the perceived needs and interests of the younger interlocutor (e.g., are not attentive listeners) and do not or cannot accommodate to some of the younger adult's speech habits (e.g., a faster speech rate), their speech may be perceived by younger adults as non-accommodating and/or

patronizing. The result may be unsatisfying interactions and the laying down of affective barriers to future intergenerational encounters. Interestingly, recent research suggests that some aspects of older adults' non-accommodating stance may carry over to their communication with same-age peers.

Theoretical Accounts of Intergenerational Speech Styles

The speech accommodations that characterize intergenerational communication, and the consequences of their use, can be elegantly accounted for by principles from communication accommodation theory and derivative models. Communication accommodation theory states that individuals adapt their communication behaviors to the perceived needs and desires of a conversational partner in accordance with their own needs and desire to identify with the other person and his or her social group identity. In other words, people engage in communicative behaviors that reflect categorization of others in terms of whether they align with their own personal and social identities (in-group vs. out-group). These intergroup categorizations are driven by the positive and negative stereotypes one has of particular social groups, the attitudes and communicative behaviors that follow from these perceptions, and the frequency and quality of one's interactions with members of each group. For example, younger adults tend to more comfortably and frequently associate with other younger adults than older adults, and vice versa. As a result, young people naturally consider other young people as part of their in-group and older adults as an out-group. Age-based perceptions of oneself in relation to out-group members are reinforced by sociocultural values, beliefs, and practices concerning the aging process, which, if predominantly negative, engender negative stereotypes of and behaviors toward older (or younger) adults. On the other hand, one's personal experiences with out-group members may be more positive than negative (e.g., within a family, or close friends), which may mitigate or reverse one's stereotypes about the out-group and lead to more appropriate accommodating communicative behaviors. It is important to keep in mind, however, that even positive stereotypes may not always lead to desirable communication behaviors and outcomes since each adult may respond differently to being classified according to a particular positive stereotype (e.g., as a doting grandmother, or an open-minded youth).

Misguided stereotypes can lead to inappropriate communication behaviors toward older or younger adults, which in turn creates barriers to effective intergenerational communication. Ryan and colleagues captured the relationships between stereotypes and their triggering cues, behaviors, and consequences in a communication predicament of aging model. **Figure 1** represents a modified version of the predicament (and enhancement) model, integrating many features from the original model and a few additional elements from similar models. In this figure, communication begins with an encounter between an older and a younger interlocutor. Based on a number of personal and contextual factors that link to aging cues (e.g., the older adult's role as a grandfather and/or a person with dementia, living at home or in a nursing home, demonstrating limited physical and/or communicative behaviors), stereotyped expectations may be activated in the younger adult that classify the older person as being intellectually, functionally, and/or socially impaired, none of which may be true. For example, expected declines in the older adult's memory may lead to anticipated poor recall of persons' names, presumed hearing loss may imply difficulty understanding messages and keeping on topic, and perceptions of closed-mindedness may constrain the selection of conversational partners. These perceptions can lead to overaccommodating behaviors (e.g., simplified grammar and vocabulary, louder and slower speech) or underaccommodating behaviors (e.g., deflecting comments, cutting a conversation short, avoiding communication with the person), which position the person as incompetent or incapable of engaging in meaningful communication. The older individual who is the target of such behaviors may infer that he or she is on the decline and, consequently, experience loss of self-esteem and personal control and have less desire for social interaction. These reactions may, in turn, reinforce stereotypes held about and by older adults and perpetuate over- or underaccommodating communication behaviors in subsequent encounters. In a similar negative feedback loop, older adult stereotypes of younger adults as being irresponsible and naive and lacking communication skills may lead to disapproving comments and/or dominating the conversation. Younger adults' reactions to such inappropriate accommodating behaviors may include inattentiveness, withdrawal from the conversation, loss of self-esteem, reluctance to seek out future encounters with older adults, and reinforcement of age-based stereotypes.

In response to the negative feedback loop of the predicament model, Ryan and colleagues introduced a communication enhancement model of aging. In this model, depicted in **Figure 1** by the enhancement loop, the person interacting with a younger or older adult views him or her as an individual rather than as a member of a stereotyped social category, having

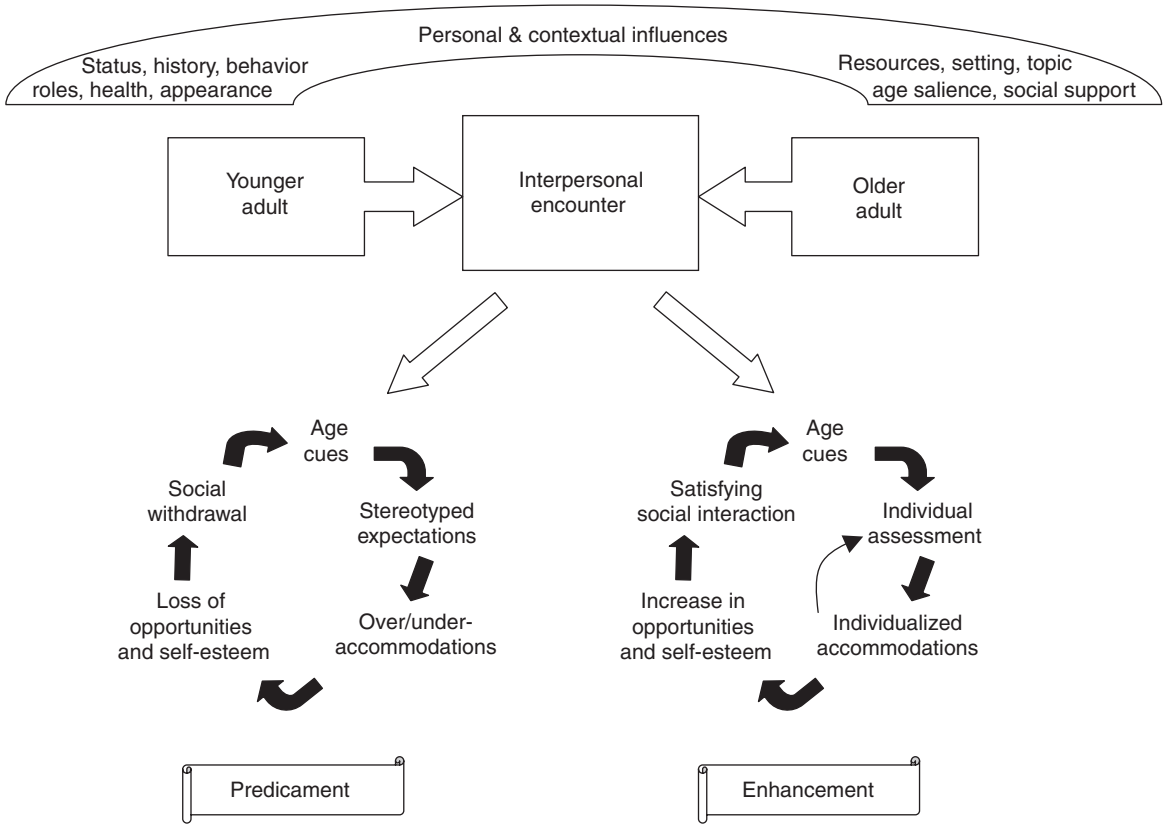

Figure 1 Predicament and enhancement models of intergenerational communication. Adapted, with significant modifications, from Ryan EB, Meredith SD, MacLean MJ, and Orange JB (1995) Changing the way we talk with elders: promoting health using the communication enhancement model. *International Journal of Aging and Human Development* 41(2): 89–107, with permission.

strengths and preferences as well as limitations and needs. The interlocutor actively listens and observes rather than making preconceived judgments. Both verbal and non-verbal behaviors are assessed and reassessed to determine what communication accommodations are appropriate and effective for that individual. The interlocutor elicits and takes into account personal and contextual factors that either support or undermine the individual's value as a human being and his or her opportunities for engaging in meaningful social interaction. For example, if an older adult is perceived to have communication difficulties, the interlocutor could caringly explore the nature and source of these in relation to retained abilities, seek input from family members, and/or find out what strategies or resources are available to facilitate the individual's participation in communication. Should a younger adult be perceived by an older adult as having a naive perspective on a topic, the older adult could encourage the younger adult to share his or her personal experiences related to the topic. In showing such an interest, the older adult may find that his or her own experiences may be solicited by the younger adult. As a result of such individualized assessments, accommodations, and reassessments, older and younger adults are more likely to perceive themselves as competent communication partners, leading to an increase in their self-esteem and a desire for further communication. The positive feedback loop thus ends and begins again with the individual's self image and value reinforced and the communication partners experiencing satisfaction with the encounter.

Cross-Cultural Comparisons of Intergenerational Speech Styles

Much of the research on speech styles has been based on perceptions of intergenerational interactions in North American and European societies. Recently, however, more cross-cultural studies of intergenerational speech styles have been conducted. Comparisons of Western (Australia, Canada, New Zealand, United States) and Eastern (China, Hong Kong, Japan, Korea, Philippines, Thailand) nations have led the way, in part because of predicted East–West differences in the importance placed on interdependence in the family and the degree of respect and honor paid to older adults. Such differences were

expected to yield more positive stereotypes of aging and limited use of elderspeak in societies that have a history of holding stronger views of filial support.

Findings from this research indicated that, contrary to expectations, younger people in East Asian societies viewed communication with non-family older adults as more effortful and problematic and viewed older adults as less accommodating than did younger adults in Western societies. They also reported having fewer positive stereotypes of aging compared to their Western counterparts. At the same time, younger adults in Eastern countries seemed to endorse filial piety. The apparent contradiction in responses can be accounted for by these adults' coexisting private (more autonomous and negative) and public (more collective and positive) views of aging. Research findings also indicated that there may be as much variability across different Eastern nations as there is between the East and West. For example, Japanese young adults showed more positive perceptions of aging than did their Western counterparts. Thus, investigations attempting to examine intergenerational communication through a cultural lens would be wise to take into account social and contextual factors that produce intracultural and intra-individual variability in communication patterns.

Further research is warranted to explore inter- and intracultural variability and how privately voiced stereotypes in different countries play out in public intergenerational interactions. In addition, while comparisons of the East and West are a good start, there is a need for research in other countries and with other cultural groups. Finally, because many interpersonal interactions in Western elder care settings are between staff and residents who do not share linguistic and cultural backgrounds, research is needed that addresses the nature of communication and use of speech accommodations in intergenerational and intercultural interactions (*see* Comparative and Cross-Cultural Studies; Cultural and Ethnic Influences on Aging).

Promoting Positive Communication between Younger and Older Adults

A logical point of intervention for enhancing communication across the life span would target the recognition of and reaction to age-based cues (see **Figure 1**). It is here that attitudes and choices are manifested in either stereotype-based accommodations or individualized accommodations. Since stereotype-based speech accommodations may be employed unconsciously and without malicious intent, the first step in curbing their use would be to raise a person's awareness of what under- and over-accommodations are, why they are employed, and their potentially deleterious consequences on communication outcomes. Nurturing such an awareness will require directing attention to the power and subtlety of stereotypes and ageism as these surface in many forms and contexts in people's lives. In addition, younger and older adults need to acknowledge and respect the legitimacy of their interlocutor's conversational goals and strategies for reaching those goals. Enhancing intergenerational communication will thus require, as noted by Ryan and colleagues, that younger and older people (1) strive for a balance between respect and accommodation by maintaining high expectations for communication of respect, combined with measured assertiveness that guides the conversational partner in selecting appropriate speech accommodations, and (2) promote contexts for interaction that allow time for such adjustments and reward communication successes.

In order to promote positive perceptions of aging through intergenerational interactions it is of course necessary that opportunities for intergenerational contact and communication be available and encouraged. Unfortunately, such opportunities have diminished as a result of greater personal mobility in many societies and the consequent geographic dispersion and institutional segregation in communities and families. To reverse this trend, it will be essential that all sectors of society reconsider the importance and benefits of life span communication and think of creative ways to facilitate younger and older adults coming together for meaningful positive communication. A couple of exemplary efforts in this regard have been older adults from community senior groups visiting and/or helping children in schools and school-aged children visiting seniors in their residences. Through efforts like these, and vigorous advocacy from an increasing older adult population, new opportunities for communication by and with older adults can be realized.

See also: Ageism and Discrimination; Caregiving and Caring; Comparative and Cross-Cultural Studies; Cultural and Ethnic Influences on Aging; Dementia: Alzheimer's; Generational Differences: Age-Period-Cohort; Hearing; Information Processing/Cognition; Language and Communication in Aging; Language Disorders: Aphasia; Long Term Care; Markers of Aging; Vision.

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Stress: Physiological

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Glossary

Heat Shock – Exposure of cells or organisms to elevated temperatures, usually 4–5°C above basal or core temperatures.

Heat Shock Genes – A class of genes preferentially expressed during cellular stress. Classes of heat shock genes are designated by the size (molecular weight) of the proteins that they encode.

Heat Shock Proteins (HSPs) – A collection of proteins also known as molecular chaperones that have multiple and vital functions. These functions include shuttling proteins from within and without the cell, disaggregating damaged proteins, tagging proteins for degradation, protecting newly synthesized polypeptides, folding new and old proteins, enhancing enzymatic activity during stress, and acting as molecular brakes for transcription (e.g., glucocorticoid receptor).

Physiological Stress – Any condition, including perturbations in heat, that creates an unfavorable environment for survival of cells, organs, or organisms.

Introduction

Age can be characterized as a period of declining responses to physiological stress. Conversely, new studies suggest that longevity is linked to a robust response to physiological stress at the cellular and molecular level. Thus, a key question is how age affects cellular stress responses and what measures can prevent its decline.

Under duress, cell and tissue survival depends not only on the severity and type of stress but also on the cellular reaction. Physiological stress occurs with perturbations in the ambient environment such as temperature fluxes or oxygen deprivation. Physiological stress also occurs when cells or organs experience homeostatic perturbations involving nutrient deprivation, osmotic shock, radiant energy, infection, and inflammation. Obviously, extreme environmental conditions limit survival, but fortunately numerous adaptive responses to physiological stress increase the chance of weathering aberrant conditions until they subside. Furthermore, chronic physiological stress may evoke a long-term adaptive process called tolerance. Understanding reactions to stress likely holds the key to solving many acute and chronic conditions afflicting the elderly such as hypoxic heart injury, oxidative brain injury and nephrotoxicity. The fact that stress responses can be pharmacologically manipulated with medications and plant medicinals offers further hope that better

neuro- and cardioprotection can be achieved as one strategy to prevent functional declines with age. With this in mind, an overview is provided here of what is known about the cellular stress response and how age changes fundamental adaptive processes.

Molecular Responses to Stress

The cellular stress response was first dubbed the heat shock response. At least four decades ago, work with fruit flies revealed that transient heat exposure elicited a unique pattern of chromosomal puffing. Later, heat-induced changes in chromosomal structure were associated with increased expression of a class of genes called heat shock genes. Dispersed among several chromosomes as multiple family members, these genes contribute to cellular vitality under normal conditions as well as during stress. Even though initial observations were made in fruit flies, heat shock genes are conserved in all living organisms. Given the importance of these genes, two key issues have been how heat shock gene expression is regulated and how the heat shock proteins function. We now know that the so-called heat shock response is really a subset of a more comprehensive cellular stress response. Specific responses occur during ultraviolet light exposure, oxidant injury, DNA damage, and glucose deprivation. Some of these responses overlap with the heat shock response, and others appear unique. **Table 1** lists many known inducers of the cellular stress response. An intriguing aspect of this list is how so many divergent factors trigger a common cellular response. The net result is enhanced cellular protection from otherwise lethal conditions. Curiously, one stressor can lead to cellular protection from other stressors. For example, heavy metal exposure will result in a response that confers protection from heat. Both these stressors induce protein damage, which signals the cell to shut down usual transcriptional and translational activities and to switch toward expression of heat shock and other stress proteins.

Table 1 Categories of environmental problems and examples of inducers of the heat shock response or its equivalent

Ambient energy	
Heat	
Ultraviolet light	
Toxins and metal accumulation	
Heavy metals	Herbamycin A
Ethanol	Sodium azide
Hemin (iron)	Dinitrophenol
Nicotine	
Lipid perturbations	
Arachidonate	
Synthetic prostaglandins	
Sphingosine	
Protein damage	
Nutrient deprivation	
Hypoglycemia	
Hypocalcemia	
Amino acid analogs	
Pharmacological agents	
Sodium salicylate	
Indometacin	
Alkylating agents	
Pathogens	
Viruses: adenovirus, herpes, influenza	
Bacteria: actinobacillus	

To trigger the cellular stress response, specific DNA-binding proteins or transcription factors are activated. Current evidence suggests that two-thirds or more of heat-inducible genes require activation of an intracellular protein called the heat shock factor (HSF1). Once HSF1 associates with the promoter region of a stress gene, it bends DNA in collaboration with other transcription factors so as to heighten RNA polymerase activity. Consequently, higher levels of messenger RNA (mRNA) encoded by the stress genes are produced and ribosomes preferentially translate these stress mRNAs into stress proteins.

Stress proteins serve multiple functions and historically have been referred to as heat shock proteins (HSPs). These proteins are classified according to their size or molecular mass. Broadly, HSPs are composed of high-, middle-, and low-molecular-mass species, the most common of which is the heat shock protein 70 (hsp70) (molecular mass = 70 kDa). Most HSPs exist under normal conditions, and their levels increase during stress.

HSPs have multiple functions during normal conditions that assume greater importance during stress. One of the functions of cellular stress or HSP is a chaperoning function whereby other proteins are shuttled from one cellular compartment to another. Stress proteins earmark damaged proteins for degradation. They help disaggregate and possibly even refold damaged proteins. Stress proteins protect newly synthesized proteins and help them fold into a functional form. Certain enzymatic activities may be protected or enhanced by stress proteins during aberrant conditions, and in some instances the stress proteins will function as molecular brakes for gene expression.

One of the key features of the cellular stress response is that it is a paradigm of inducible gene expression, thus offering a fairly well understood system for examining the question of whether age affects transcriptional controls. Pivotal to induction of the cellular stress response is the heat shock transcription factor. Several HSFs have been isolated in various species, but HSF1 appears to be the primary

mediator of heat shock gene expression. **Figure 1** depicts a model of how HSF1 functions in human and many eukaryotic cells. Basically, HSF1 exists in the cytoplasm and nucleus of cells as a horseshoe-shaped molecule folded upon itself. Through signals induced by stress, cytoplasmic HSF1 translocates to the nucleus, possibly facilitated by HSP. HSF1 unfolds and associates with other molecules of HSF1 to form a trimeric structure capable of binding DNA. The activated HSF1 trimer binds to specific DNA sequences called heat shock elements located in the promoter region of heat shock and other genes. The heat shock elements are composed of repetitive nucleotide sequences guanine, adenosine, and adenosine (GAA). Interactions between HSF1 and the GAA sequences in the promoter region of the heat shock genes appear to be sufficient to fully increase heat shock gene expression, although other co-factors and protein–protein interactions fine-tune gene expression. HSF1 phosphorylation and HSF1–protein–DNA complexes further affect RNA polymerase processivity and the rate of mRNA production (*see* DNA and Gene Expression).

Despite continuous stress, HSF1–DNA binding attenuates. This is an important observation because how HSF1 falls off the promoter is likely to provide clues as to how age prevents its initial binding to DNA. How HSF1 resumes its inactive form is not clear, but phosphorylation and disassembly by HSPs are touted as two potential means of deactivating HSF1. A putative inhibitor to HSF1–DNA binding may play a role in regulating stress responses, and overactivity of this inhibitor could be a clear mechanism for age to alter the stress response. HSF1 levels do not increase during stress, so this relatively long-lived transcription factor appears to be regulated by post-translational controls. After recovery from an initial stress, HSF1 is less sensitive to reactivation by further stress. This change in HSF1 sensitivity to stressful stimuli has important implications for the aging process. For instance, prolonged exposure to stress, such as when neuronal cells are chronically exposed to neurotoxic amyloid, could very well diminish future cellular stress responses.

Age-Dependent Changes in the Stress Response

Several models of senescence demonstrate that heat shock gene expression is altered with time (see **Table 2**). One of the original observations concerning the cellular stress response was by A. Y.-C. Liu, who found that late-passage, fetal lung-derived fibroblasts (IMR-90) did not express HSP in response to a 42°C heat shock, whereas early passage cells did. Both the

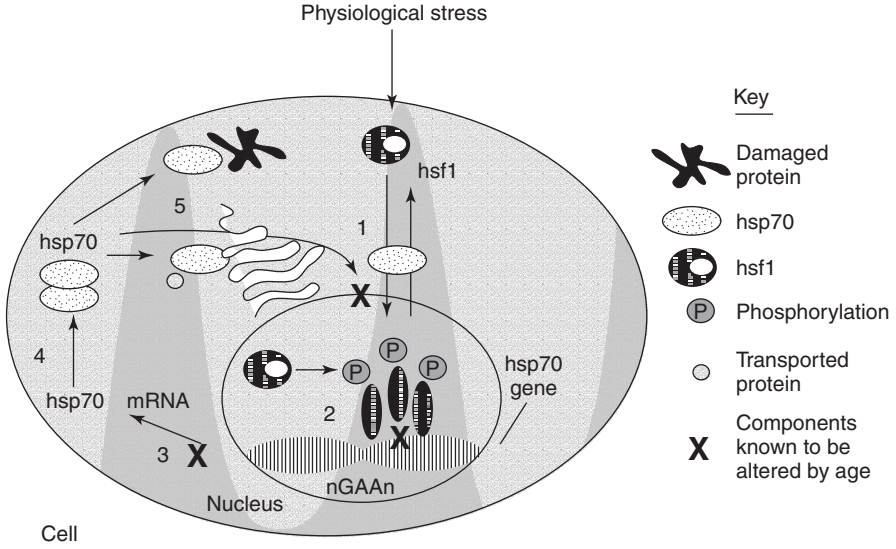

Figure 1 A model of the cellular regulation of the human stress response. Numbers correspond to the various transcriptional and translational steps necessary for induction of the stress response. (1) HSF1 under homeostatic conditions is folded upon itself in the cytoplasm and nucleus. Environmental stress triggers its unfolding, and HSF1 accumulates in the nucleus as a homotrimeric complex that binds to *cis*-acting elements in the promoter region of heat shock and other 'stress genes.' (2) During the course of acquiring DNA binding potential, hsf1 becomes increasingly phosphorylated and drives RNA polymerase II activity to a higher level. (3) Single exon mRNA for heat shock genes such as the hsp70 gene accumulate and are preferentially expressed by the translational apparatus. (4) Heat shock protein levels increase, and the dimeric form of hsp70 dissociates and forms complexes with other proteins. (5) Hsp70 and other molecular chaperones serve multiple functions, including protection of newly synthesized proteins, disaggregation of damaged proteins, protection of essential enzymes, and regulation of specific transcription factors.

Table 2 Representative studies that examined age-dependent changes in heat shock gene expression

Model of senescence	*Type of stress*	*Old versus young response*
Human peripheral blood mononuclear cells (Kishimoto)	42°C heat shock	~30% reduction of maximal hsp70 transcription rate relative to young donor cells
Human diploid fibroblasts IMR-90 (Liu)	42°C heat shock	~30% reduction in levels of hsp70 mRNA in late passage cells
Aged rats (Holbrook)	Whole animal exposure to 40°C	Core body temperature of aged animals is lower than young animals. 60–75% reduction in hsp70 mRNA levels in old rat brain, lung, and skin. No changes noted in whole liver
Rat hepatocytes (Richardson)	42.5°C heat shock	40% reduction in hsp70 mRNA levels in old donor hepatocyes

early- and late-passage cells expressed the same class of HSP after heat shock, but cells of population doubling level (PDL) 51 produced significantly less HSP than PDL 18 cells when incorporation of ^{35}S-methionine into newly synthesized proteins was analyzed by autoradiography of proteins separated by SDS-polyacrylamide gel electrophoresis. Both the initial rate of synthesis and the absolute amounts of many HSPs were reduced in the late-passage cells when compared to the early-passage cells during heat shock. Basal levels of HSPs at 37°C did not change with serial passage of the IMR-90 cells, thus emphasizing the loss of inducible gene expression as cells become senescent. Similar results were found with serial passage of other human diploid cell lines such as TIG-1.

Both Northern blot and nuclear run-off analysis confirmed that the decreased induction of HSP in late-passage cells is due to a transcriptional problem. Because late-passage cells maintain constitutive gene expression such as the β-actin gene, age does not cause a general perturbation in the RNA polymerase activity over time. Rather, age disrupts signaling of heat shock gene expression.

Age-induced attenuation of heat shock gene expression in senescent fibroblasts is attributed to decreased levels of HSF1–DNA binding activity. Either a negative regulator of HSF1 or post-translational modifications that prevent DNA binding appear to be the prime considerations for loss of HSF1–DNA binding with age. 'Mixing' experiments in which extracts from late-passage cells are added to extracts from early-passage cells produce inconclusive results. Most of these experiments do not suggest the presence of a dominant negative inhibitor of DNA binding produced by senescent cells. However, alternative results have been obtained in rat hepatocytes, and serial fractionation of cellular extracts from old animals produce at least two types of inhibitors to HSF1–DNA binding.

An intriguing issue has been whether other members of the HSF family somehow interfere with heat-inducible HSF1 with age. This hypothesis has been tested, and HSF1 was not found to be associated with other family members of HSF1, thus suggesting that unique protein factors or lipid regulators interact with HSF1 and attenuate its DNA-binding capacity.

The relationship of the cell cycle to stress induction of HSF1 may have some relevance to aging. Serum-starved or quiescent cells lack HSF1–DNA binding activity after being stressed by factors other than heat. Thus, the mechanism by which late-passage fibroblasts lose heat-inducible HSF1–DNA binding activity is subject to continued investigation.

Even though an altered heat shock response has been identified in senescent fibroblasts, a primary concern is whether other models of aging exhibit a similar perturbation. Overall, the consensus is that age does indeed attenuate all or some of the heat-inducible responses, especially in humans. The reason for variation in the observations is that different cell types and different conditions are analyzed. For example, Zurivich and Zhou found that proliferating human T cells have a much more robust heat shock response than quiescent T cells. Part of the reason is that transformation of T lymphocytes into T lymphoblasts increases HSF1 levels, thus age-dependent differences between T lymphocytes and lymphoblasts are greater in the former than in the latter. Likewise, quiescent B cells have little to no HSF1, thus making it impossible to replicate observations in T cells. Thus, even within one organ system, e.g., the immune system, significant variation in the stress response needs to be understood before criticizing the literature for divergent results on the aging stress response. Much of our understanding of how age affects the stress response comes from rodent studies. The laboratories of N. Holbrook and A. Richardson each have shown how restraint stress and *in vitro* rodent cell cultures are impacted by age and stress. Growing fibroblasts isolated from young and aged donor rats have comparable levels of thermal-inducible heat shock gene expression; however, when cells became confluent, little to no hsp70 gene expression occurred in old donor fibroblasts. After the examination of more than 20 individual animal cultures, it was concluded that age led to approximately a 50%

decline in hsp70 mRNA levels after heat shock. This decline in hsp70 mRNA levels appeared to occur in both skin and lung fibroblasts, with the largest age-dependent difference in hsp70 mRNA levels manifested in skin fibroblasts. Whole tissue analysis of inducible hsp70 mRNA levels showed results similar to cultured cells. Importantly, no age-dependent decline in β-actin mRNA was found, thus confirming that quantitative decreases in hsp70 mRNA after stress are specific and not general age-related problems with RNA polymerase activity.

In contrast to human cells, rodent mRNA for the high- and low-molecular-weight HSPs did not show an age-dependent decrease in their expression after heat shock. The reason for this discrepancy is not clear. Differences in culture conditions and the fact that the aged donor rodent fibroblasts retain their proliferative potential, whereas the late-passage human fibroblasts do not, suggest that the growth state of cells intersects with the aging process. The fact that the vast majority of tissue exists in a postmitotic state also suggests that age-dependent changes in gene expression during stress are likely to be most apparent in non-regenerative organs.

An interesting result of whole animal studies and physiological stress is that physical restraint of male Wistar rats induces a neurohormonal stress response, resulting in elevated heat shock gene expression. Although there may be strain-specific variations in this response, age causes nearly a 75% reduction of inducible mRNA levels in adrenal tissue of restrained rats. The induction of hsp70 mRNA seems to be linked to ACTH because hypophysectomized animals did not exhibit increased hsp70 mRNA levels after restraint. Paradoxically, cultured adrenal cells do not exhibit a stress response when exposed to various concentrations of ACTH, thus other circulating factors may be involved. Alternatively, neurohormonal stress may sensitize the adrenal glands to hypoxic damage, which in turn activates the stress response. This paradox represents one of the difficulties in correlating *in vivo* findings with observations from tissue culture experiments. Nevertheless, induction of the heat shock response in restrained Wistar rats is an encouraging observation regarding the biological relevance of heat shock gene expression. Additional experiments on exercising rodents show that vigorous physical activity increases the heat shock response in muscle tissue. Consistent with many similar studies, aging attenuates the myocyte stress response in both muscle and heart.

Heat is not the only regulator of HSF1 and the stress response. In addressing the issue of whether HSF1–DNA binding can be triggered by physiologically relevant elevations in temperature (39–40°C), it was found that exposure of cells to inflammatory modulators such as arachidonate can activate HSF1–DNA binding at temperatures that normally do not do so. Furthermore, HSF1–DNA binding can be detected in the peripheral blood mononuclear cells from a febrile human donor. Activation of HSF1 by 42°C in cultured cells appears to be recapitulated by febrile temperatures *in vivo* and thus reinforces the link between *in vitro* research models and actual human responses to heat.

Mechanistically, loss of heat shock gene expression during senescence is multifactorial. Because the expression of many other genes such as β-actin does not appear to be affected by senescence, altered heat shock gene expression results from age-dependent changes in the signaling of the stress response. A putative candidate in the signaling cascade is HSF itself. Most studies to date indicate that aging is accompanied by a diminution in HSF–DNA binding activity. The lower levels of HSF–DNA binding activity have been documented in gel shift assays that utilize a short synthetic piece of DNA. To date, no one has directly proven loss of HSF1–DNA binding with age in intact cells, but *in situ* studies show loss of intranuclear HSF1 with age and provide the best evidence that cell culture results recapitulate actual aging processes. Perhaps the biggest ongoing controversy is whether diminished HSF–DNA binding with age is due to an inhibitor. This inhibitor is proposed by some investigators who found that extracts from old donor or senescent cells partially block HSF–DNA binding in extracts from young donor cells. Others have not found an inhibitor in these mixing experiments, but this is not surprising since known inhibitors of other transcription factors are not always revealed by this method. Shamovsky and Gershon have found three novel factors that regulate HSF1: an HSF1 inhibitor, elongation factor 1 alpha, and a large non-coding RNA. The HSF1 inhibitor blocks HSF1 trimerization, whereas the other two factors promote HSF1 activation. An increase in activity of the former and/or decreased activity of the latter is thought to account for age-dependent loss of HSF1–DNA binding in aging rats. Jurivich and Zhou have found that extracts from old donor human T cells that exhibit low levels of HSF1–DNA binding also have the capacity to block HSF1 trimerization *in vitro*.

In addition to HSF1 co-factors, post-translational modifications of HSF1 during senescence may render it less capable of binding to DNA. In yeast, phosphorylation of a specific amino acid residue will attenuate HSF–DNA binding, thus the possibility exists that age-dependent modifications of HSF1 alter its capacity to bind to the promoter region of the

heat shock genes. Stress-induced transient modification of HSF1 by one or more protein kinases has been observed in cultured cells. The purpose of HSF1 phosphorylation is generally thought to be to enhance expression of heat shock genes. A handful of stress-inducible kinases have been identified, and at least one of these was found to have a lower activity in senescent cells during heat shock.

Although age-dependent perturbations in the regulation of HSF1 are likely to account for changes in heat shock gene expression, other possibilities may disrupt inducible gene expression. Protein–protein interactions in the promoter region of the heat shock genes may be altered during senescence, and proteins constitutively bound to the heat shock promoter may be modified in a fashion that does not fully support transactivation of the genes. Consistent with these possibilities, one of the proximal heat shock promoter proteins (Sp1) declines in its DNA binding with age. Furthermore, mitogen activation of heat shock gene expression is reduced in elderly donor peripheral blood lymphocytes. Because the proximal promoter controls growth-mediated heat shock gene expression, it can be inferred that control of the proximal heat shock promoter is affected by age.

As investigators seek the mechanism for altered heat shock gene expression during senescence, it is important to ask whether there is a functional consequence of age-dependent changes in this response. One question is whether altered gene expression leads to changes in the basal or inducible levels of one or more HSPs. Thus far, both the human senescent fibroblast model and rodent models of aging reveal that HSP levels are not affected by age in the non-stressed state. Experiments consistently show that inducible hsp70 levels are diminished with age. The affect on other HSPs is less clear-cut, and in one instance there appeared to be an increase in the number of HSPs in old fruit flies. Nevertheless, changes in levels of hsp70 or other HSPs could alter the sensitivity of aged donor cells to injury and death. Research has found that growing primary fibroblasts and lymphocytes from aged donors exhibit a greater sensitivity to heat-induced cellular death when compared to cells from young donors. The growth state of the cell clearly impacts its sensitivity to stress. Growing cells, especially those in the mitotic or DNA synthesis phase of the cell cycle, are most sensitive to stress-induced injury and death. Quiescent cells show a resistance to stress-induced cellular death, and factors other than HSPs may mediate this cytoprotection. Some investigators cite HSP phosphorylation as a means to confer cytoprotection rather than HSP accumulation. The idea that increased levels of HSPs contribute to cytoprotection comes from experiments in which HSPs are overexpressed in a cell line after transfection with a HSP-containing plasmid. The cell line then becomes resistant to cell death induced by extreme heat or cytokines such as tumor necrosis factor. Based upon these studies, a potential goal in clinical gerontology would be to enhance the human heat shock response.

Manipulation of the heat shock response during senescence has several possibilities. Pharmacological stimulation of the heat shock response appears to have the most promise. Non-steroidal anti-inflammatory drugs (NSAIDs) affect the key modulator of the heat shock response, HSF1. Treatment of cells with salicylate and other NSAIDs lowers the temperature set point for activating this transcription factor by heat. Thus, NSAID-treated cells respond to heat stress much more vigorously than untreated cells. The net result is that pretreatment of cultured epithelial cell lines enhances their resistance to thermal stress. Similar to NSAIDs, a select number of plant medicinals and other standard medications enhances transcription factor activation responsible for the heat shock response. These observations give promise to reconstitution of the cellular stress response in the elderly. To do so, we can expect organ protection against chronic and acute conditions such as neuroprotection in face of Alzheimer's dementia and possibly myocardial protection during ischemic events.

Recent studies implicate the heat shock response in longevity. For example, caloric restriction prolongs life and prevents the age-related decline in the induction of hsp70 expression. Human centenarians do not manifest the 50% decline with age in HSF1 activation, and they maintain a robust induction of hsp70 during stress. Remarkably, genetic manipulation of HSF1 in nematodes confers even longer life spans in this short-lived species. Further understanding of the heat shock response during senescence has the potential to lead to improved cellular function with age and ultimately extend an active life span.

Conclusions

Aging alters the molecular response to physiological stress. The diminished induction of hsp70 gene expression during senescence primarily results from perturbations in triggering the heat shock transcription factor. Both the proximal and distal promoter of the hsp70 gene are affected by age. The functional consequence of altered heat shock gene expression during aging includes accumulation of damaged protein and cell death. The fact that baseline HSP gene expression increases with senescence suggests that age is a low-grade inflammatory and stressed state. Prolonged accumulation of damaged proteins may

act as endogenous toxins such as with amyloid. Accumulated damage in cells under low-grade stress further attenuates the inducible heat shock response. Thus, age results in maladaptive stress responses that further decrease the chances of cellular survival in aged donor organs.

Loss of cellular stress responses with age may have an evolutionary twist. Aberrant cellular stress responses with age may be a genetic means of heightening cellular or whole organism death due to environmental stress, thus assuring a continuous turnover of a population. Curiously, long-lived strains of nematodes and yeast have higher levels of HSPs than the wild-type strains, thus suggesting a critical link between longevity and stress proteins.

Finally, a recent observation that HSPs reverse prion protein malformations in yeast suggests that clinical strategies to upregulate HSP in the human population could be a valuable adjunct to treat neurodegenerative disorders associated with age. Additional knowledge of basic molecular responses to physiological stress potentially could lead to new clinical interventions that would help reverse age-dependent decrements in cytoprotection (*see* Cellular Aging: Growth Factors and Cellular Senescence).

See also: Cell Death; Cellular Aging: Growth Factors and Cellular Senescence; DNA and Gene Expression.

Further Reading

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Stroke

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Glossary

Antiplatelet Agents – Medications such as aspirin and ticlopidine that reduce stroke risk by preventing platelets from clumping or aggregating.

Carotid Endarterectomy – A surgical procedure to reduce stroke risk by removal of atherosclerotic blockage in the carotid artery.

Risk Factors – Antecedent physiologic (genetic), lifestyle, or dietary factors that increase the likelihood of developing a disease.

Stroke – The sudden or subacute onset of neurologic deficit caused by occlusion or rupture of a cerebral artery.

Stroke Subtypes – Specific pathophysiologic mechanisms that underline cerebral ischemia or hemorrhage.

Vascular Dementia – Dementia caused by stroke.

Introduction

Stroke is the sudden onset of neurologic deficit caused by occlusion or spontaneous rupture of a cerebral artery. Stroke is the third leading cause of death in the United States and ranks as the most common disabling and lethal neurologic disease of adult life. It is estimated that there are 400 000–500 000 new strokes, 3 million stroke survivors, 150 000 deaths attributable to stroke annually in the United States. Furthermore, the direct and indirect health-care costs are estimated to total $30 billion yearly.

Stroke is unique among neurologic diseases as it has a high prevelance and burden of illness, high economic cost, and safe and effective prevention measures. Although stroke may occur at any age, it is most common among the elderly. There is an exponential rise of stroke with age that leads to an approximate doubling of stroke frequency in each successive decade from middle age onward. Thus, the elderly, the most rapidly expanding segment of our society, are most likely to be afflicted by stroke and its disabling complications.

This article will review stroke epidemiology, clasification and pathophysiology, treatment and prevention, and consequences. Topical discussions will emphasize how stroke affects the elderly.

Stroke Epidemiology

Epidemiology is the study of the distribution and determinants (causes) of disease in our population. Epidemiologic study helps answer scientific questions relating to who is most likely to be afflicted by a disease, why the disease has occurred, and if there will be an epidemic of the disease. The distribution of disease refers to its prevalence and incidence. Prevalence is the number of persons with the disease in a defined population at a given point in time. Incidence is the number of new cases of disease that develop in a defined population during a specified period of time. Prevalence alerts us about the magnitude of a disease in our society and aids public health planners in making decisions about allocation of health-care resources for the disease. Incidence is an indicator of risk or who is most likely to develop the disease. Finally, disease determinants or risk factors are antecedent physiological, dietary, or lifestyle habits that increase the likelihood of developing a disease. The presence of a risk factor increases the probability of disease. However, not every person with the risk factor will develop the disease, nor will the absence of the risk factor ensure absence of the disease. As a group, the elderly are unique as they often have multiple stroke risk factors (*see* Epidemiology).

Mortality

Stroke death rates have shown a steady decline in the United States since the early 1900s with about a 1% per year decline. In the late 1960s and early 1970s death rates from stroke began to fall by 5–7% per year, and the greatest decline has been in the older age groups. However, since 1979 the annual rate of decline of stroke mortality began to slow considerably. Overall, stroke death in the United States increases with age, is higher among men than women except in the oldest age group, and is highest among African Americans.

The reason for the accelerated stroke mortality decline in the United States in the early 1970s has been debated. Possible explanations include improved antihypertensive therapy, declining stroke incidence, improved stroke survival, reduction in the severity of stroke, or some other factor. The precise explanation for the deceleration in stroke mortality trends since 1979 remains uncertain, but it parallels decreasing social and economic conditions for many and a leveling off of a national trend for continued improvement in blood pressure control.

Prevalence

In general, stroke prevalence increases exponentially with advancing age. Stroke prevalence is estimated to range between 500 and 600 per 100 000 in the West but is generally higher in the East.

Incidence

Stroke incidence increases with age and approximately doubles in each successive decade. In general, the incidence of stroke is higher in men than women and is substantially higher in US Blacks as compared to Whites. The relative risk of brain infarction is higher among African American women when compared to white women, and African Americans have a higher incidence of brain hemorrhage. **Table 1** demonstrates the exponential rise in annual stroke incidence with age according to the Framingham Study.

Over time (1950–1979) stroke incidence has declined substantially. However, more recently (1979–1984) it has been noted that stroke incidence may be increasing. Among persons with ischemic heart disease, this may be due to increased survival. Further information is needed about the effect of increased detection of stroke by up-to-date neuroimaging techniques, levels of blood pressure of treated and nontreated persons, and treatment of other cardiovascular disease risk factors.

Table 1 Average annual stroke incidence per 1000 persons by age (Framingham Study 36-year follow-up)

Age[a]	*Atherothrombotic brain infarction*		*Stroke (all types)*	
	Men	*Women*	*Men*	*Women*
45–54	0.8	0.7	2.2	1.2
55–64	2.1	1.2	4.5	2.8
65–74	4.3	3.7	9.3	8.0
75–84	8.5	6.8	19.2	15.0

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[a] Age in years at Biennial Exam.

Table 2 Stroke risk factors that may be modified

1. Hypertension
2. Heart disease
   a. Coronary heart disease[a]
   b. Congestive heart failure[a]
   c. Left ventricular hypertrophy[a]
   d. Atrial fibrillation
3. Diabetes mellitus[a]
4. Cigarette smoking
5. Alcohol consumption[b]
6. Hyperlipidemia[a,b]
7. Asymptomatic carotid stenosis
8. Transient ischemic attack

[a] Treatment feasible but benefit for stroke prevention as yet not established.
[b] Classified as less well-documented risk factor for stroke.

Risk Factors

There is a substantial body of epidemiologic knowledge about stroke risk factors. Such factors may be classified as modifiable and non-modifiable and well-documented and less well-documented. The following discussion will emphasize major host risk factors that are well established and potentially modifiable. These factors are listed in **Table 2**. Previously mentioned non-modifiable risk factors such as race, sex, and age will not be reviewed.

Hypertension Hypertension is considered to be the most important treatable risk factor for stroke. The risk of stroke rises with increasing blood pressure, and the relative risk of stroke among hypertensives is about three to four times greater than non-hypertensives. Systolic, diastolic, or combined systolic and diastolic hypertension confer substantial stroke risk.

The prevalence of hypertension increases with age. In the Framingham study, 38.2% of those 50–59 years had hypertension, whereas 71.6% of those 80–89 years were hypertensive. Although hypertension remained an important risk factor for stroke, there was a decline in its estimated relative risk and the number of strokes attributable to it with advancing age. Isolated systolic hypertension is highly prevalent with advancing age, and there is at least a twofold increased risk of brain infarction among those 65–84 years with systolic pressures greater than 160 mmHg and diastolic pressures consistently below 95 mmHg.

Heart disease Coronary heart disease, left ventricular hypertrophy, congestive heart failure (CHF), and atrial fibrillation are all independent risk factors for brain infarction. The prevalence of these factors also generally increases with advancing age but does not attain the magnitude of prevalence in the elderly as does hypertension. However, the estimated relative risk and number of strokes attributable to atrial fibrillation substantially increases with age such that by age 80–89 years atrial fibrillation may increase stroke risk by 4.5 times and account for almost 24% of strokes (*see* Cardiovascular System).

Diabetes mellitus Diabetes mellitus is an independent risk factor for brain infarction. According to the Framingham study the relative impact of diabetes may be greater in women than in men, and its impact on the risk of brain infarction does not diminish with advancing age. Rigorous treatment of diabetes retards some vascular complications but has not been proved conclusively to prevent stroke.

Cigarette smoking Stroke risk increases in a stepwise manner with the number of cigarettes smoked. With cessation of cigarette smoking, stroke risk may reverse after 2–5 years. Cigarette smoking is less prevalent in the elderly, and its impact as a risk factor in the aged may be less obvious. This was the case for men in the Framingham study. However, women aged 65–94 years continued to have a substantial effect from cigarette smoking relative to those 35–64 years.

Alcohol consumption Epidemiologic study suggests that moderate alcohol consumption reduces the risk of brain infarction. Whereas abstention or infrequent alcohol use may increase risk slightly, heavy consumption may increase risk substantially. For brain hemorrhage it seems that the risk of stroke increases directly with the number of daily drinks. The risk of

brain hemorrhage may reverse with reduction in heavy alcohol consumption.

There is a paucity of information about the role of alcohol consumption as a risk factor for stroke in the elderly. It is likely that this factor makes a much smaller relative and absolute contribution toward stroke occurrence in the elderly compared to, for example, hypertension and atrial fibrillation (*see* Alcohol and Drugs).

Hyperlipidemia There is mounting evidence to link blood lipids to risk for brain infarction. Further study will be required to clarify this relationship. Hypercholesterolemia is an important modifiable risk factor for coronary heart disease. However, lower levels of serum cholesterol are associated with an increased risk of brain hemorrhage. The effect of blood lipids on stroke risk may be less substantial in the very old.

Asymptomatic carotid atherosclerosis With advancing age there are degenerative cerebral vessel wall changes termed atherosclerosis. These atherosclerotic deposits or plaques cause the larger cerebral arteries to narrow and may compromise blood flow to the brain. With increasing severity of atherosclerosis in the carotid artery, there is an associated increased risk for stroke and heart attack, and death due to stroke, heart disease, or other vascular cause. Recently, it has been shown that removal of high-grade carotid atherosclerotic plaque by a surgical procedure called carotid endarterectomy may reduce the risk of stroke and death in patients who have had no prior stroke symptoms (*see* Atherosclerosis).

Transient ischemic attack Transient ischemic attack (TIA) is a transient focal neurologic deficit lasting less than 24 hours that is referable to diminished perfusion to a focal area of the brain. It is estimated that the 5-year risk of stroke following TIA is about 33%. Most strokes occur within the first year of TIA with up to 21% in the first month, one-half within 3 months, and two-thirds within 6 months. The occurrence of TIA increases with advancing age.

Storke Classification Pathophysiology

Stroke is not a homogeneous disorder. Rather, it is a group of syndromes with definable subtypes and distinct pathophysiology. The discovery and recognition of stroke subtypes has been one of the leading advances in stroke research. The classification scheme for major stroke subtypes is listed in **Table 3**. The following discussion will review the pathophysiology of individual stroke research. The classification scheme for major stroke subtypes is listed in **Table 3**. The following discussion will review the pathophysiology of individual stroke subtypes. One must keep in mind that stroke-related terms such as TIA, reversible ischemic neurologic deficit (RIND) (partial neurologic deficit that lasts more than 24 hours but resolves completely or almost completely within several days), and completed stroke (focal stroke deficit that comes on abruptly, stabilizes, and does not progress) provide information about the time course of stroke and the extent of the neurologic deficit, but little information about the way in which cerebral blood vessels have become affected. More specific terms that indicate the pathophysiologic mechanism are preferred (see **Table 3**).

Table 3 Classification of stroke by pathophysiologic mechanism

Ischemia
Atherothrombotic brain infarction (cerebral thrombosis)
Lacunar brain infarction
Cerebral embolic brain infarction
Cardiogenic
Artery-to-artery
Infarct of undetermined cause
Non-atherosclerotic brain infarction
Hemorrhage
Subarachnoid hemorrhage
Intraparenchymal hemorrhage
Non-atherosclerotic brain hemorrhage

Stroke may be broadly divided into ischemic and hemorrhagic pathophysiologic subtypes. Ischemic stroke occurs when there is blockage of a cerebral artery by in situ clot (thrombus) or embolism (clot from an artery or the heart, or fragments of the atherosclerotic vessel wall that travel distally to occlude the artery). Brain hemorrhage occurs when a major cerebral vessel ruptures and blood leaks into the brain tissue or surrounding areas. With both ischemic and hemorrhagic stroke, the brain is deprived of blood that carries needed nutrients such as glucose and oxygen. Neurologic deficits such as weakness (hemiparesis), sensory signs and symptoms, visual loss, speech impairment, and language dysfunction (aphasia) may occur. Of the two major stroke subtypes, ischemic stroke constitutes about 85% of cases and hemorrhagic stroke about 15%.

Atherothrombotic Brain Infarction

Atherosclerosis is a degenerative vessel wall disease that results in narrowing of major cranial and systemic arteries. The primary pathology is the atherosclerotic plaque. The plaque contains fat deposits, smooth muscle hyperplasia, and other elements that lead to occlusion of the vessel lumen. As cerebral atherosclerosis progresses, signs of cerebral ischemia

(i.e., lack of blood flow) may develop as the narrowed artery thromboses or as embolic debris dislodges and travels downstream. Atherosclerotic plaques have a predilection for major arterial bifurcations and branch points such as the internal carotid artery origin, junction of the vertebral and basilar arteries, and initial segments of the middle and posterior cerebral arteries.

A leading theory proposes that atherosclerosis occurs in the setting of elevated blood cholesterol and hypertension. The blood vessel wall is damaged by hypertension, and this leads to deposition of fat components from the bloodstream and other atherosclerotic changes. Atherosclerotic plaques are common in the elderly and increase with age.

Lacunar Brain Infarction

In contradistinction to atherothrombotic brain infarction, in which large cerebral artery pathology underlies the stroke, lacunes result from occlusion of deep penetrating branches of the larger cerebral arteries. The infarct (small 'lake') may measure only several cubic millimeters. The vascular pathology underlying this syndrome, lipohyalinosis, differs from atherosclerosis. Lipohyalinosis is a degenerative disease in which lipids and hyaline form in the vessel wall to block blood flow. Lacunar infarction may also be caused by microatheroma that obstructs the orifice of a small penetrating artery at its origin from the large parent artery. In addition, lacunes may be caused by microembolism or other arteriopathies.

Lacunar infarction is often encountered in the clinical setting of sustained hypertension. Multiple lacunar infarction may be an important cause of stroke (vascular) dementia in the elderly.

Cerebral Embolism

Cerebral embolism may arise from two major sources: the heart and the arterial blood vessel wall. Certain cardiac conditions such as atrial fibrillation, myocardial infarct, and cardiomyopathy lead to stasis of blood and clot formation in the major heart chambers. A portion of the clot may dislodge and travel into the cerebral or systemic circulation to cause ischemia. Cardiac valve disease (e.g., rheumatic heart disease) can also serve as a source for cardiac embolism. Finally, atherosclerotic debris (fragments of cholesterol, thrombus, and fibrin-platelet material) from the aorta or carotid artery may embolize to cause cerebral ischemia.

Cardiac source embolism is now considered a major cause of cerebral ischemia (causing up to 30% of cases) and has reached this status with modern advances in cardiac diagnostic technology. Non-valvular atrial fibrillation (i.e., atrial fibrillation not related to valvular heart disease) is the most important source of cardiac embolism to the brain and is an important risk factor for stroke in the elderly.

Infarct of Undetermined Cause

Despite advances in stroke diagnostic technology, a disproportionately high percentage of cases cannot be classified as one of the traditional stroke subtypes. Infarct of undetermined cause (IUC) includes both those cases of undetermined cause with extensive stroke diagnostic workup and those with less extensive work-up. This category of stroke may include up to 40% of cases. Some are thought to be caused by a non-atherosclerotic stroke mechanism, and many are probably a form of occult cerebral embolism.

Non-atherosclerotic Brain Infarction

This type of stroke usually occurs when there are underlying systemic disorders that cause stroke by secondary mechanisms. The secondary mechanism may be a systemic illness with associated cerebral arteriopathy, vasculitis, cardiac involvement, or hypercoagulable state. Brain infarction associated with street-drug abuse and consequent cerebral arteriopathy is such an example. Infarction of hemorrhage may occur. These disorders are generally more prevalent in young adults and have less importance in the elderly.

Subarachnoid Hemorrhage

The most common cause of primary subarachnoid hemorrhage (SAH) is ruptured intracranial aneurysm. The usual type of aneurysm is saccular in form and projects as a tiny outpouching or blister-like structure from the cerebral artery. Most saccular aneurysms arise from the carotid artery at the level of the posterior communicating artery, the anterior communicating artery region, or the middle cerebral artery bifurcation. The cerebral territory bound by these blood vessels and some from the vertebrobasilar circulation has been collectively called the circle of Willis.

Clinically, the onset of SAH is abrupt and associated invariably with headache. Blood under arterial pressure ruptures into the subarachnoid space (the protective cerebrospinal fluid-filled space bound by a thin membrane) or adjacent brain tissue and causes neurologic damage. The major cerebral arteries that course through the blood-laden subarachnoid space may develop 'vasospasm' that leads to cerebral infarction.

The incidence of aneurysmal SAH rises with age. However, when compared with ischemic stroke subtypes, there is a disproportionate number of aneurysmal SAH among women and the young.

Intraparenchymal Hemorrhage

Intraparenchymal hemorrhage (IH) arises commonly from deep penetrating cerebral arteries affected by lipohyalinosis, microaneurysm formation, and arteriosclerosis with severe degeneration of medial smooth muscle cells. As blood extravasates from the ruptured artery, neurologic deficit arises as adjacent brain tissue is disrupted, displaced, and compressed. The sites of predilection of IH are similar to those of lacunar infarction as in both cases the deep penetrating arteries are involved. These sites include commonly the putamen, thalamus, pons, and cerebellum.

IH usually occurs in the setting of chronic hypertension. In the elderly it may also occur in association with cerebral amyloid angiopathy (CAA). CAA is characterized by deposits of amyloid in the media and adventia of small and medium-sized cerebral arteries usually located in the superficial layers of the cerebral cortex and leptomeninges. The resultant cerebral hemorrhage is usually located superficially in one of the major brain lobes (so-called lobar hemorrhage). Lobar hemorrhage may also occur with other conditions including hypertension, bleeding disorders, and arteriovenous malformation. CAA increases with advancing age and is associated with histopathologic and clinical features of Alzheimer's disease.

Diagnostic Studies

An elderly patient who has had a brain infarct, TIA, RIND, or brain hemorrhage will undergo a stroke diagnostic workup to define the underlying stroke mechanism. Once the underlying cause of stroke is determined, stroke treatment can be tailored appropriately. There are different levels of diagnostic stroke workup based on the risk associated with the procedure. One usually proceeds in a stepwise manner ordering non-invasive tests before invasive ones. The goal is to avoid higher risk invasive procedures if possible. Before obtaining stroke diagnostic studies in the elderly, one must weigh the following questions: (a) Is the patient's stroke condition so severe that an extensive battery of stroke-diagnostic studies would be contraindicated or would not alter one's treatment plan? (b) Are there comorbid conditions that would contraindicate stroke diagnostic or therapeutic modalities? (c) Are the patient and caregiver aware of and in agreement with the proposed diagnostic and treatment options given the inherent risks and benefits?

The vigorous or well-selected geriatric patients are good candidates for stroke diagnostic procedures and treatments. However, discretion must be exercised by the clinician before embarking on an aggressive and extensive stroke diagnostic workup in these patients.

Table 4 lists stroke diagnostic studies by ischemic and hemorrhagic stroke subtype and level of invasiveness. Cranial computed tomography (CT) is usually performed on an emergent basis as it is an excellent tool for distinguishing infarct from hemorrhage. Once this distinction is made, the workup may proceed according to the algorithm in **Figure 1**. Magnetic resonance imaging (MRI) of the brain is generally more sensitive than CT in stroke diagnosis but may not diagnose hemorrhagic stroke until well after its onset.

Treatment and Prevention

Treatment of stroke may be divided into three stages: (a) the hyperacute period; (b) the secondary

Table 4 Stroke diagnostic studies

	Invasive?
Brain infarction	
Neuroimaging	
Cranial computed tomography (CT)	No
Magnetic resonance imaging (MRI)	No
Magnetic resonance angiography (MRA)	No
Single photon emission computed tomography (SPECT)	No
Conventional cerebral angiography	Yes
Carotid duplex ultrasound	No
Transcranial doppler (TCD)	No
Cardiac studies	
Ambulatory electrocardiogram (EKG)	No
Echocardiography	
Conventional (transthoracic)	No
Transesophageal (TEE)	Yes
Procoagulant blood studies and other studies	
Lupus anticoagulant, anticardiolipin antibodies, proteins S and C, antithrombin III, homocysteine	No
Lumbar puncture	Yes
Brain hemorrhage	
Neuroimaging	
CT	No
MRI	No
MRA	No
Conventional cerebral angiography	Yes
Other studies	
Lumbar puncture	Yes

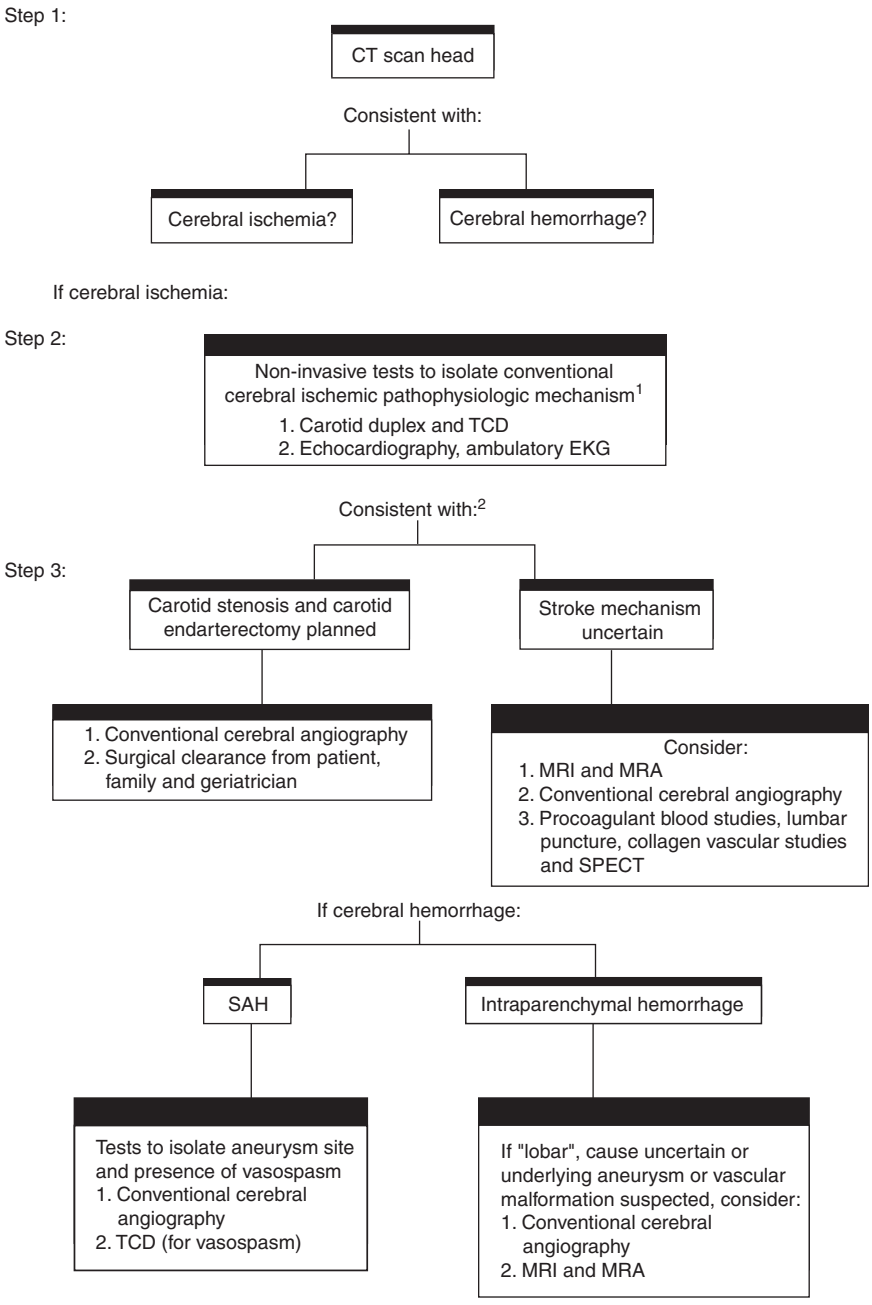

Figure 1 Stroke diagnostic algorithm. If CT is negative for SAH, perform lumbar puncture to isolate blood in cerebrospinal fluid if clinical presentation is consistent with SAH; MRI and MRA may be performed but are not the most sensitive procedures to isolate aneurysm site. Routine blood studies should include a screen for bleeding diathesis; MRI is useful as a follow-up study to rule-out underlying lesions such as neoplasm and to chart the course of hemorrhage resolution. [1]To be performed in conjunction with routine blood studies, electrocardiogram and chest X-ray. Some experts would consider MRI and MRA as Step 2 tests. [2]Carotid duplex and TCD are used to define high-grade extracranial and intracranial large artery atherosclerotic occlusive disease. Echocardiography and ambulatory EKG define cardiac source embolism. Lacunar infarction is generally diagnosed in the absence of atherosclerotic mechanism or cardiac source embolism and in the presence of typical lacunar syndrome (eg., pure motor hemiparesis, pure sensory stroke, clumsy-hand dysarthria, ataxic hemisparesis).

prevention period; and (c) the primary prevention stage. The hyperacute period encompasses the earliest stage and generally includes the time from onset of cerebral ischemia or hemorrhage through the first 7 days. During this stage the brain is vulnerable to cerebral ischemia. A window of opportunity exists to rescue marginally functioning brain cells in the 'ischemic penumbra' (i.e., the brain tissue at risk in the

shadow zone of the compromised cerebral blood flow). The exact therapeutic window of opportunity for hyperacute cerebral treatment is debated, but may be less than 12–24 hours. After the hyperacute period efforts are aimed at preventing recurrent stroke (secondary prevention) and at rehabilitation. During the hyperacute and early secondary stroke prevention phases, high-quality medical, nursing, and rehabilitative management is critical to prevent aspiration pneumonia, deep venous thrombosis and pulmonary embolism, urinary tract infection, cardiac complications, and other medical consequences of acute stroke. These are listed in **Table 5**. The primary prevention stage aims to prevent a *first* stroke by dietary, lifestyle, and medical strategies designed to alter the community's and individual's risk of stroke.

The following discussion will focus on acute treatment and prevention of ischemic stroke. The reader is referred to several excellent references for a review treatment and prevention of brain hemorrhage.

Hyperacute Treatment

Acute loss of blood flow to the brain results in synaptic transmission failure when blood flow drops to about 18 ml/100 g/min and membrane pump failure and cell death at about 8 ml/100 g/min. The mainstay of hyperacute management is administration of medication to protect the neuron against cell death or improve brain blood flow and delivery of oxygen, glucose, and other nutrients. Most hyperacute agents are classified as pharmacologic or cell protectants, antithrombotics, thrombolytics, or hemorheologic treatments based on their mechanism of action. Many are still undergoing clinical trial testing. As of yet there is only one hyperacute stroke treatment, tPA when given within 180 min of ischemic stroke onset, that has been proved conclusively to reduce stroke morbidity or death. Most experts believe that hyperacute stroke treatment should be administered as soon as possible ('Time is brain') and no later than 6–8 hours after stroke onset.

Table 6 summarizes key hyperacute stroke treatments and their status with regard to clinical testing. Should these agents prove to be effective, the future of hyperacute treatment may include combination therapy.

Secondary Prevention

There is substantial clinical trial literature on antiplatelet agents and recurrent stroke prevention. It is widely held that the risk of recurrent stroke or death is reduced significantly in TIA or mild stroke patients who take the antiplatelet agents aspirin or ticlopidine. In the first 2 years of treatment, ticlopidine may be more effective than aspirin in secondary stroke prevention; however, its adverse event profile may be less favorable. The latter factor plus cost and monitoring considerations have engendered controversy about the indications for ticlopidine based on risk–benefit analysis. There is also controversy about the proper dose of aspirin of secondary stroke prevention. Some experts argue for lower doses (e.g., 75–325 mg), whereas others adhere to higher dose regimens (500 mg or 975–1300 mg).

Table 5 Medical complications of acute stroke and their prevention

Complication	*Prevention measure*
Aspiration pneumonia	1. Frequent oral-pharyngeal suctioning if indicated 2. Swallow evaluation and appropriate diet 3. Frequent turning and positioning 4. Protect airway and intubate if indicated
Loss of cerebral autoregulation	1. Maintain mild to moderate arterial hypertension 2. Avoid rapid lowering of blood pressure unless a vital organ is compromised
Dehydration	1. Maintain hydration status with 0.45 or 0.9 normal saline 2. Avoid hypotonic fluids or those containing glucose
Skin breakdown/decubitus ulcer formation	1. Regular examination of skin, especially dependent portions, for evidence of breakdown 2. Special pressure mattress and frequent turning of patient
Urinary tract infection	1. Avoid indwelling urinary catheters
Venous thromboembolism	1. Pressure-gradient stockings or pneumatic-compression stockings 2. Anticoagulant if not contraindicated
Seizure	1. Observe for occurrence of seizure 2. Anticonvulsant administration if seizure occurs
Cardiac arrhythmia	1. Ambulatory electrocardiogram

Table 6 Major hyperacute stroke therapies

Type	*Results of clinical trial testing*
Cytoprotectants	
Calcium channel blockers	No major benefit
Opiate receptor antagonists	No major clinical trial underway
Barbiturates	No established benefit
N-methyl-D-aspartate antagonists	Clinical trial testing underway
Antithrombotics	
Heparin	No established benefit
Heparinoids	Clinical trial testing underway
Prostacyclin	No major benefit
Thrombolytics	
Streptokinase	No established benefit
Tissue-type plasminogen activator (t-PA)	Established benefit with administration within 3 h
Urokinase	Clinical trial testing underway
Hemorheologic treatment	
Hemodilution	No major benefit
Ancrod	Clinical trial testing underway
Pentoxifylline	No major benefit
Other	
Ganglioside (GM_1)	No major benefit

The anticoagulant warfarin is beneficial for the prevention of stroke in patients with non-valvular atrial fibrillation. Carotid endarterectomy, a surgical procedure to remove atherosclerotic plaque from the carotid artery, is the treatment of choice when there is high-grade (70–99%) ipsilateral symptomatic carotid stenosis in patients with TIA or minor stroke. For low-grade carotid stenosis (0–29%), the surgical risks outweigh the benefits, and antiplatelet therapy is recommended. For medium-grade carotid stenosis (30–69%), the answer is as yet uncertain but is the focus of ongoing study.

Secondary stroke preventatives have been studied most extensively in those in the 60–65-year age range. Clinical trial experience in the very elderly is limited. It has been shown that aspirin may not be an effective stroke preventative in patients over 75 years of age with atrial fibrillation, yet warfarin may be dangerous in this group. Carotid endarterectomy may be safely performed in well-selected older patients.

Primary Prevention

Generally, stroke, a chronic disease, has a long latent period, and primary prevention is possible. Public health strategies to prevent stroke by modification of risk factors amenable to medication, diet, or other interventions include the mass and high-risk approaches. The mass approach emphasizes lifestyle modification to achieve modest reductions in the level of the risk factor in all individuals in the population. The high-risk approach identifies individuals with high levels of a risk factor or multiple risk factors, and medication is usually prescribed to achieve substantial reductions in the risk factors(s).

There is substantial primary prevention data to show a major benefit for treatment of hypertension and use of warfarin in atrial fibrillation. More recently it has been shown that carotid endarterectomy is safe and effective in patients with high-grade (50 or 60–99%) asymptomatic carotid stenosis. Observational epidemiologic studies support the contention that cessation of smoking and heavy alcohol consumption is beneficial in reducing stroke risk. Debate exists about the efficacy of treatment of hypercholesterolemia and other blood lipid abnormalities.

There is clear evidence for substantial stroke risk reduction by treating isolated systolic hypertension in the elderly. However, in the very old the window of opportunity for primary prevention may have lapsed in regard to treatment of some modifiable risk factors. Cerebrovascular disease may be too far advanced, treatments are not safe or effective, or the absolute benefit for risk factor modification is small, as the risk factor has low prevalence and relative risk in the very old.

Consequences of Stroke

It is estimated that more than half of stroke survivors have significant residual physical disability and functional impairment. Among long-term survivors in the Framingham Study the following deficits were observed: decreased vocation function (63%), decreased socialization outside the home (59%), limitations in household tasks (56%), decrease in interests and hobbies (47%), decreased ability to use outside transportation (44%), decreased socialization at home (43%), dependence in activities of daily living (32%), dependence in mobility (22%), and relocation to a nursing home or other institutional setting (15%).

Age is an important predictor of functional prognosis in stroke. Although age does not preclude good functional outcome, it is associated with shorter survival, more comorbidity, and adverse psychosocial conditions. The most powerful determinant of functional outcome in stroke seems to be specific neurologic deficit. Severity of stroke deficit and comorbidity (medical and psychosocial) are crucial to functional outcome. Other factors that may play a role include sex, race, marital status, etiology of stroke, educational level, vocation status, financial status, and other 'intrinsic' factors such as family support and available community services.

Dementia is an important consequence of stroke. It is estimated that vascular dementia is the second

leading cause of progressive and irreversible dementia, accounting for approximately 10–20% of cases. The frequency of vascular dementia rises exponentially with age. It is generally held to be more common among men than women and may be more prevalent than Alzheimer's disease in Asia and among the very old in some countries (e.g., Sweden). In addition to age and possibly education, risk factors for vascular dementia seem to be those cardiovascular determinants that underlie stroke.

At present, vascular dementia is the only preventable form of dementia of late life. As stroke leads to vascular dementia, the prevention of stroke by modification of treatable risk factors is anticipated to result in a significant reduction in vascular dementia. However, once vascular dementia is diagnosed, there is no proven secondary preventative to reduce its debilitating cognitive effects (*see* Dementia).

See also: Alcohol and Drugs; Atherosclerosis; Cardiovascular System; Dementia; Epidemiology.

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Suicide

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Glossary

Non-fatal Suicidal Behavior – A suicidal act that the person survives.

Psychological Autopsy – The retrospective reconstruction of possible psychological causes of a suicide via interviews with family members and/or friends of the deceased. The psychological autopsy interview typically focuses on events perceived by the informants to lead to the suicide as well as possible mental disorder symptoms in the deceased.

Suicidal Ideation – Thinking or talking about killing oneself.

Suicide – Self-inflicted death.

Introduction

Suicide is self-inflicted death. In most countries reporting to the World Health Organization (WHO), including the United States, suicide rates are highest among older adults. Older men are more likely to die of suicide than older women. Of the approximately 31,000 suicides recorded annually in the United States, about 5,500 are by older adults. Most of these older adult suicides involve men of European American descent. There is variability in gender rates of suicide across ethnicities. There is also considerable variation in international rates of older adult non-fatal suicidal behavior. In general, rates of non-fatal suicidal behavior tend to be lower in older adults than in young adults. At the same time, among older adults, suicidal behavior may be indirect, involving food refusal or non-adherence to therapy. Older adults may be less communicative about their suicidal thoughts, which may increase mortality risk.

Suicide is usually defined as self-inflicted death. The term non-fatal suicidal behavior refers to the situation in which an individual survives a suicidal act. Other terms for non-fatal suicidal behavior are attempted suicide, deliberate self-harm, and parasuicide. Suicidal ideation means thinking or talking about killing oneself.

Many factors influence whether a suicidal act is fatal, including the immediate lethality potential of the suicide method as well as access to medical care. The outcome of a suicidal act is not a reliable measure of intent. Not all persons who survive a suicidal act intended to live; conversely, not all suicidal deaths are deliberate.

Terms such as attempted suicide and successful suicide should be avoided because they confound outcome with intent. Another reason for avoiding these terms is that they imply that surviving a suicidal act is a negative outcome, a failure, and that killing oneself is a positive outcome, a success.

The classification of a death or behavior as suicidal is influenced by social values and political factors. There are significant variations, both within and across countries, in the type of evidence required for a behavior to be considered suicidal. For example, in some cultures it is not even necessary for a death to be self-inflicted to be viewed as a suicide. Consider the case of ritual killing of Lusi widows by male kin in the Kaliai district of Papua New Guinea. Locals view the ritual killings of Lusi widows suicides because the widows presumably demand to be killed, as a way to avoid becoming dependent on their children. By contrast, the German and Australian authorities consider the killing of widows by kin to be murder. This example demonstrates that for an act to be recognized, reported, and recorded as a suicide, a complex cultural negotiation is required, across private and public domains, and involving the meaning and consequences of suicide within a community. This complexity should not simply be treated as a source of error in epidemiological data but rather as useful information through which understanding of suicide can be obtained and then applied to planning for suicide prevention.

This article begins with a review of the national and international epidemiology of older adult suicidal behaviors. It then considers theories and evidence on risk factors for older adult suicide in the United States. Next, it reviews dominant suicide prevention practices and proposes new directions for suicide prevention, as suggested by the research findings. The article concludes with a summary of main issues in older adult suicidal behavior and prevention.

Epidemiology

In the United States, suicide rates are highest among older adults. For example, in 2002 the suicide mortality rate for persons age 65 and older was 15.6 per 100 000, higher than the national cross-age rate of 9.9

per 100 000, and higher than the rate of 11 per 100 000 for persons age 15 to 24. This means that in 2002, older adult suicide rates exceeded those of young adults as well as national rates by 42% and 58%, respectively. Suicide is disproportionately more common among older adults as compared to young adults and the general population. Specifically, older adults represent about 12% of the population, but they account for 18% of suicides. By contrast, young adults represent 13% of the population and account for 14% of suicides. At the same time, it is noteworthy that, over the past several decades, older adult suicide rates have been declining, while young adult suicide rates have been increasing. Older adult suicide rates vary by region of the country and are highest in the west. Older adult suicide rates also vary by gender. In the United States, men age 65 and older take their own lives at six times the rate of same-aged women. Men account for over 80% of suicides among persons aged 65 and older. Among older men, those of European American descent have the highest suicide mortality. Suicide is particularly rare among older women of Native American descent. While there is a gender gap in suicide rates across ethnicities, both the magnitude of the gender gap and the specific suicide rates vary depending on ethnicity (see **Figures 1** and **2**).

Firearms are the most common suicide method among older men and women – though firearms are used in a much larger proportion of men's suicides (79%) compared to women's suicides (33%). Choice of method varies depending on ethnicity, immigration status, as well as cohort. Among Asian-Americans, for example, hanging is being replaced by firearms, concomitant with the individual's immigration status and assimilation into US culture.

According to data from countries reporting to the World Health Organization (WHO), international suicide rates are also highest among older adults. One exception is Poland. Older adult suicide rates are particularly high in Hungary, Lithuania, Latvia, and other Eastern and Central European countries, with relatively low rates in Southern European countries. Furthermore, internationally, older men are more likely to die of suicide than older women. It is important to note that information about suicide mortality, like information about non-fatal suicidal behavior and ideation, is available primarily from industrialized countries. Therefore, international suicidal behavior trends, including those available via the WHO, reflect the suicidal behavior of a unique sample of countries and may not be generalizable beyond those countries(**Figure 3**).

The significance of cultural factors in suicidal behavior is highlighted by the findings of studies of suicide among immigrants. These studies, which were conducted in countries such as the United States, Australia, and the United Kingdom, indicate that suicide rates of recent immigrants are similar to the suicide rates of country-of-origin peers than the rates of host country peers.

Information about non-fatal suicidal behavior and suicidal ideation is more limited because there are no national records of non-fatal suicidal behavior and ideation. Community studies conducted in the United States suggest that rates of explicit non-fatal suicidal behavior are lower in older adults. Among older adults, suicidal behavior may be indirect, for example, food refusal or non-adherence to therapy. Older adults may be less likely to discuss their suicidal thoughts with others, which may be a factor in their high suicide mortality. The patterns of older adult suicidal ideation and non-fatal suicidal behavior recorded in the United States may not be universal. As evidence of that, a recent multicenter European study found considerable national variation in rates of non-fatal suicidal behavior in older adults, from 14 per 100 000 in Würzburg, Germany to 111 per 100 000 in Huddinge, Sweden (**Figure 3**).

The variability in older adult patterns of suicidal behavior (non-fatal and fatal) between and within countries as well as by gender, ethnicity, and geographical region indicates that suicidal behavior is not an inevitable consequence of aging. There are clearly cultural elements in the risk for suicidal behavior among older adults. Given the cultural variability in older adult patterns of suicidal behavior, this article next focuses on older adult suicidal behavior in one country, the United States. Specifically, it critically examines theories and evidence on risk factors for older adult suicidal behavior in the United States. This approach allows exploration of risk factors within cultural context, that is, in light of local ideologies and experiences of aging and suicide. This is critical because suicide and aging may have different meanings and consequences in different cultures. Once the cultural principles of aging and suicide are understood in one national context, those principles can be applied to decoding the dynamics of aging and suicide in a different national context.

Theories and Evidence

Two theories of older adult suicide dominate the US literature. The first theory states that older adult suicide is based on mental disorders, particularly affective disorders. The second theory states that the high rates of older adult suicide can be blamed on the burdens and losses of aging, that is, aging-related losses in health, economic resources, employment, and companionship.

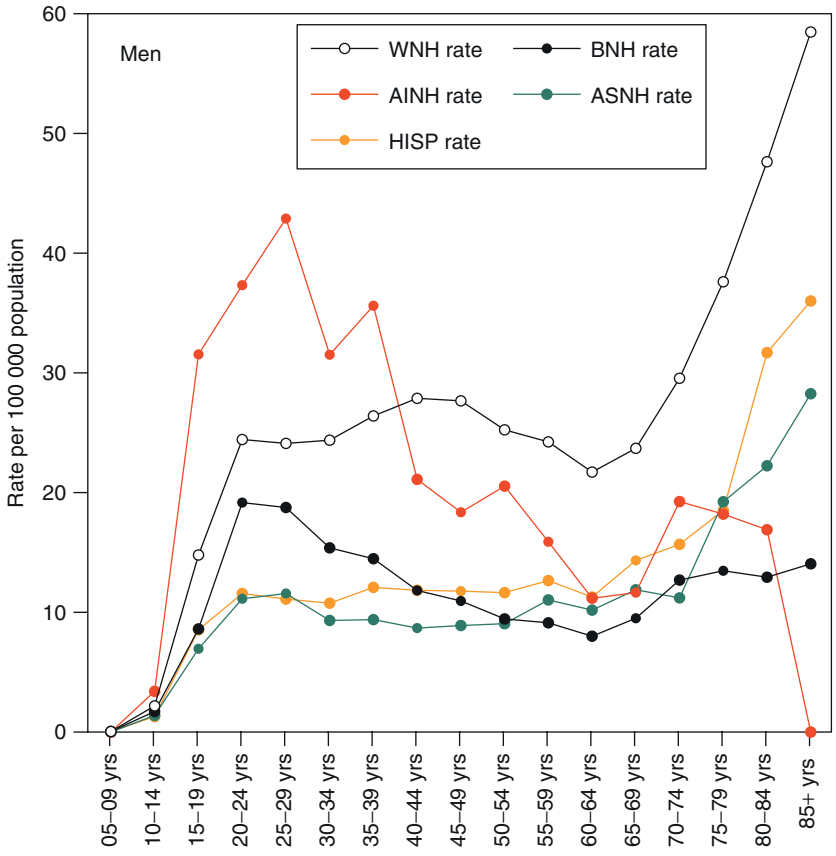


Figure 1 Men's suicide rates by ethnicity and age, 1999–2002. WNH, White non-Hispanic; AINH, American Indian non-Hispanic; HISP, Hispanic; BNH, Black non-Hispanic; ASNH, Asian American non-Hispanic. Courtesy of John L. McIntosh, Ph.D.; based on data from the Centers for Disease Control's WISQARS (Web-based Injury Statistics Query and Reporting System), February, 2005.

Retrospective, psychological autopsy studies of many individuals who died by suicide indicate that prior to their death, many of these individuals may have been diagnosable with a mental disorder. Psychological autopsy evidence suggests that some older adults who killed themselves also experienced significant health and family discord problems. These findings have been interpreted by some as suggesting that mental disorders and negative life events are in fact the main culprits for older adult suicide. A key limitation of the psychological autopsy evidence is that it is *post facto* and indirect, as it is based on post mortem interviews with family members and friends of the deceased.

If it were true that aging is intrinsically psychopathogenic and suicidogenic, then mental disorders and suicide should be most common among older adults, as compared to other age groups, and should be independent of culture. Mental disorders and suicide should also be most prevalent among the older adults who are most exposed to, and impacted by aging losses. The patterns in the United States of mental disorders and suicide across age, sex, and culture, however, do not support these predictions.

First, young adults have higher rates of mental disorders but lower rates of suicide than older adults. Second, in the United States, the highest suicide rates are found among those older adults who, as a group, and by historical privilege, have been most protected from aging losses, that is, older men of European American descent. Consider, for example, economic adversities. Older women, particularly ethnic minority older women, are more likely to be poor but are less likely to die of suicide than older men. The same is true of employment or retirement difficulties. Women (and ethnic minorities) experience more adverse employment conditions (e.g., low pay) throughout their work history, and yet they have lower rates of suicide than men. Similarly, the transition to retirement is more stressful for women than men, and yet suicide rates are lower in older women than in older men. What about interpersonal losses? Older women are more likely than older men to be exposed to, and impacted by aging-related interpersonal adversities. For example, they are more likely than men to experience widowhood, to not remarry after widowhood, and to live alone after widowhood. However, widowhood and living alone are more significant suicide

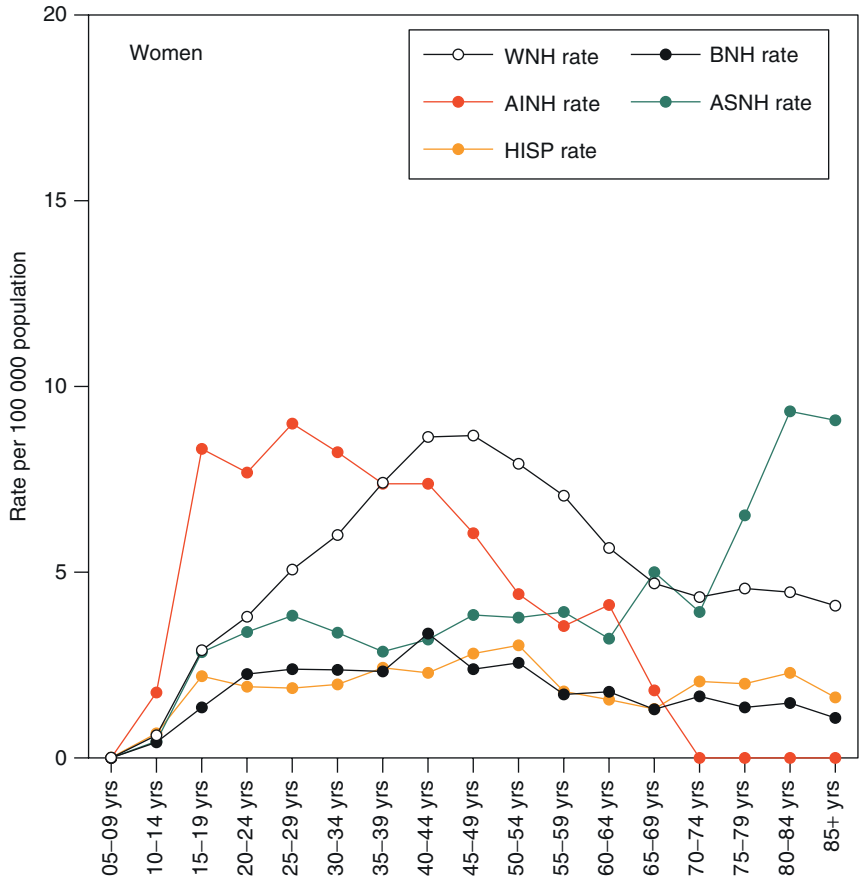
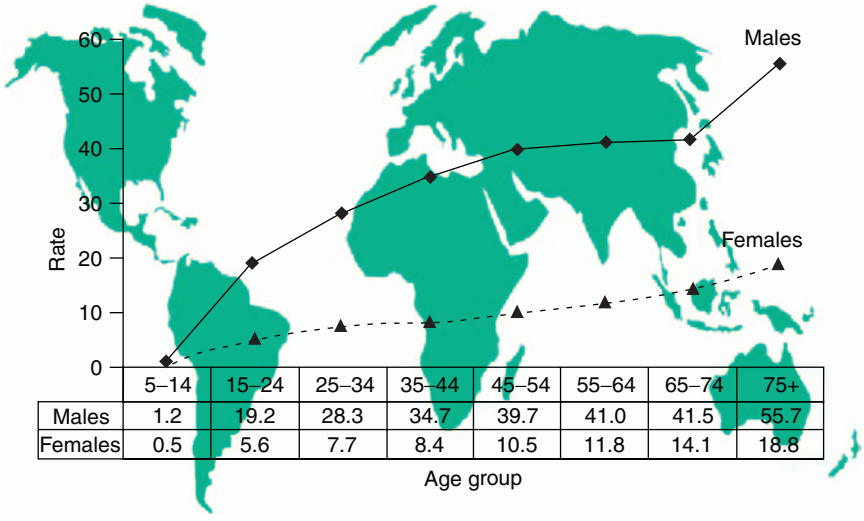


Figure 2 Women's suicide rates by ethnicity and age, 1999–2002. WNH, White non-Hispanic; AINH, American Indian non-Hispanic; HISP, Hispanic; BNH, Black non-Hispanic; ASNH, Asian American non-Hispanic. Courtesy of John L. McIntosh, Ph.D.; based on data from the Centers for Disease Control's WISQARS (Web-based Injury Statistics Query and Reporting System), February, 2005.



	5–14	15–24	25–34	35–44	45–54	55–64	65–74	75+
Males	1.2	19.2	28.3	34.7	39.7	41.0	41.5	55.7
Females	0.5	5.6	7.7	8.4	10.5	11.8	14.1	18.8

Figure 3 1998 suicide rates (per 100 000) for men and women and across age groups for countries that report suicide mortality to the World Health Organization. Retrieved from http://www.who.int/mental_health/prevention/suicide/suicide_rates_chart/en/index.html with permission from the World Health Organization.

risk factors for men than for women. Finally, the data on health and disability show greater exposure to and impact of illnesses and disabilities in women as compared to men. And yet physical illness is a more important suicide risk factor for men than for women. In conclusion, women and ethnic minorities are more, not less, exposed than men to the economic, interpersonal, and health losses and adversities that have been blamed for the high rates of older adult suicide, and yet they have lower rates of suicide than men. Men, particularly men of European American descent, are more protected from aging adversities but are more likely to die of suicide than women. Stated differently, men are more vulnerable to suicide when facing interpersonal loss, interpersonal discord, social isolation, and health adversities.

One way to make sense of the gender and cultural paradox of older adult suicidal behavior in the United States is to consider dominant gender meanings of aging and suicide. Studies conducted among primarily European American respondents indicate that older adult suicide is perceived as more acceptable than suicide in other age groups. Second, suicide in response to a physical illness is viewed as more understandable than suicide following any other stressor. In fact, suicidal persons are generally perceived as less maladjusted if their suicidal behavior was precipitated by a physical illness.

Clues to understanding the overrepresentation of males among the suicides can be found in studies of gender meanings of suicide. There is evidence of a dominant assumption, in Western countries, that suicide is a masculine act. Durkheim, a historically influential European sociologist, formulated a theory stating that killing oneself requires a kind of intelligence and courage that, according to him, could only be found in men. Studies conducted with predominantly European American samples confirm that suicide is considered male behavior. These studies reveal that male suicide is considered less foolish, less wrong, and more powerful and permissible than female suicide. They also show that suicide is viewed as more masculine and more potent than non-fatal suicidal behavior (so-called 'attempted suicide'). Among European Americans, suicide 'attempts' are treated as feminine behavior. In addition, feminine persons are expected to 'attempt' suicide more than masculine persons. Males have been found to be particularly critical of other males who 'attempt' suicide and 'fail' to kill themselves. Finally, there is evidence that suicide by older men of European American descent is interpreted as a sign of masculine courage and determination.

Some have argued that men's suicide mortality is simply a function of males being more likely than females to use immediately lethal suicide methods, such as firearms. Men's use of firearms is also taken by some as an indication that males have higher suicidal intent than females. Studies do indeed show that, in the United States, firearm access increases suicide risk, particularly for males. It is important to remember, however, that males' choice of suicide method takes place in a culture that considers guns a 'hard,' masculine method and that views surviving a suicidal act as unmasculine. In addition, guns are highly accessible in the United States, especially to men. In industrialized countries outside the United States firearms are much less likely to be used in suicide, by either males or females. In developing countries, the most common suicide method for both males and females tends to be poisoning.

Finally, psychological autopsy personality evidence shows that older adults who kill themselves (who are usually men) may be particularly rigid, conscientious, traditional, habit driven, emotionally unaware, and unable to access and articulate affect, including negative affect (and thus potentially more able to hide their distress from friends, family and providers). From a gender perspective, it may be seen that the personality characteristics associated with suicide risk are consistent with socially expected masculine behavior. Thus, once again it appears that adoption of conventional male behavior may be a factor in males' heightened risk for suicide, particularly in late adulthood.

In conclusion, the findings on the cultural meanings of gender, aging, and suicide generated by studies with primarily European American samples suggest that older male suicide may be encouraged by the dominant belief that suicide is more acceptable for older adults and for males. Given prevailing ideologies, males, particularly males of European American descent, may feel that if they engage in suicidal behavior, they can not allow themselves to survive it, because that would mean failing at suicide, even though success in this case means death. The association of suicide with physical illness, which has emerged in psychological autopsy studies and which is particularly strong for males, is not surprising considering dominant ideologies of masculinity. European American men may be particularly vulnerable to killing themselves following an illness or disability due to a connection, in their culture, between physical integrity, physical power, physical autonomy, and masculinity.

Prevention

Dominant theories of older adult suicide have focused on mental disorders and the stresses of aging. Consistent with these theories, suicide prevention has

tended to reach out to populations and individuals who are at risk, especially as related to mental disorders and stressful life events. In other words, suicide prevention programs have privileged a secondary and tertiary focus and used selective or indicated approaches so as to reduce the immediate risk of symptomatic individuals or vulnerable groups. For example, there is also substantial literature on the treatment of suicidal and/or depressed individuals. Both biological (psychopharmacological as well as electroconvulsive therapy) and psychotherapy approaches have been explored. In addition, there is a growing literature on educating front-line providers, particularly physicians, in detecting suicidality and depression in older adults presenting for medical care. This latter approach was triggered by findings that many older adults made contact with physicians within 1 month of killing themselves.

A key axiom in prevention is that targeting pathogens (via a primary prevention program) before they have a chance to generate morbidity or mortality is more parsimonious than treating individuals (via secondary and tertiary prevention programs) after they have been affected. A second axiom is that a universal approach to prevention, that is, an approach that focuses on reducing risk and enhancing resilience for the entire population, is more efficient than an indicated approach focusing on symptomatic, high-risk individuals. The argument is that large numbers of individuals at small risk will give rise to more morbidity than small numbers of high-risk individuals.

The variability in susceptibility to suicidal behaviors depending on gender, culture, and geographical location certainly makes a case for universal primary prevention approaches. One tested universal primary prevention approach has been to reduce firearm access. Evidence shows that the 1994 Brady Handgun Violence Prevention Act has reduced firearm suicides in individuals age 55 and older. A potentially fruitful and yet untried avenue for universal primary prevention of older adult suicide is public education. A public education campaign for the prevention of older adult suicide could start with promoting awareness about the unique vulnerability of older adults to suicide. In addition, this campaign could educate about the variability in older adult suicide risk depending on sex, ethnicity, and geographical location. Furthermore, a public education campaign should address the pervasive cultural acceptability of older adult suicide and the association of suicide and masculinity. More nuanced educational programs should also be developed for professionals who have contact with older adults, including care providers. These programs for professionals should start with an assessment of the professionals' beliefs about gender, aging, and suicidal behavior. Building on this information, the educational programs should then educate professionals about dominant ideologies of gender, aging, and suicide (including the idea that suicide is relatively acceptable under conditions of physical illness) as well as address misinformation these professionals may believe about older adult suicide (such as the idea that suicidal ideation and hopelessness are a normal experience of aging). Finally, professionals involved in secondary prevention (e.g., clinicians working with suicidal clients) should be trained to add an educational component to their therapy. This may involve exploring and then challenging their older clients' dysfunctional beliefs about gender, aging, and suicide, including the belief that killing oneself is a relatively powerful masculine behavior. In all cases, educational messages should build on an understanding of the gender, aging, and suicide beliefs of the group they target, because these group cultural beliefs may be unique, and also because cultural beliefs constantly change and evolve.

Summary

In the United States and in nearly all countries reporting suicide mortality data to the WHO, older adults have the highest suicide rates of all age groups. It is important, however, to keep in mind that our knowledge of older adult suicidal behavior comes primarily from Western and/or industrialized countries and that, therefore, older adult vulnerability to suicidal behavior can not be assumed to be universal. What we know for sure is that there is significant variability in older adult fatal and non-fatal suicidal behavior within countries (based on gender, ethnicity, and geographical location) as well as over time. Also, data from the United States reveal an interesting paradox: suicide is most prevalent among those older adults, men of European American descent, who by historical privilege have been most sheltered from the adversities of aging. In other words, older women and ethnic minorities experience more aging adversities but are less likely to die of suicide than older men. Collectively, this evidence indicates that suicide is not an inevitable consequence of aging, illness, disability, or even depression, as it has long been theorized in Western countries, including the United States. There are clear cultural factors in the risk for, and expression of suicidal behavior for women and men, and across cultures. Studies on the cultural meaning of gender, aging, and suicide have provided some light on the culture and gender paradox of older adult suicidal behavior. A dominant belief among European Americans is that suicide is a relatively powerful masculine response to aging adversities.

Older adult suicide prevention has tended to focus on at-risk individuals and vulnerable groups and to use strategies aimed at reducing morbidity in affected individuals and groups (secondary prevention) or at minimizing impact and reducing morbidity recurrence (tertiary prevention). A reduction in the prevalence of older adult suicide, however, also requires universal primary prevention approaches. One tested universal primary prevention approach is to reduce firearm access. A promising but yet-untested primary prevention strategy with older adult involves developing a public educational campaign. One aim of the campaign would be to educate about the unique vulnerability of older adults to suicide. Another aim would be to challenge dysfunctional social beliefs about suicide, such as the belief that suicide is a masculine act, or the belief that suicide is relatively permissible and understandable for older adults, particularly when they suffer from illnesses and disabilities.

See also: Death and Dying; Ethics and Euthanasia; Mental Health; Psychological Well-Being.

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Syncope

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Glossary

Neurally Mediated Syncope – Syncope believed to result from an exaggerated cardiac and neurocardiac reflex that leads to acute vasodilation of the arterial and venous beds and relative or absolute bradycardia.

Presyncope (also called Near Syncope) – A condition in which patients feel as though syncope is imminent.

Syncope – A sudden, transient, self-limited loss of consciousness associated with the inability to maintain postural tone, usually leading to falling.

Tilt Table Testing – A non-invasive provocative test used to determine a patient's susceptibility to neural mediated syncope.

Introduction

Syncope, which is defined as a self-limited loss of consciousness, is more common in older persons than in any other age group. Age-related physiological changes of heart function, blood pressure, baroreflex sensitivity, and cerebral blood flow, together with the

high prevalence of chronic illnesses and the use of multiple medications, predispose older adults to syncope. The main causes of syncope in this population are orthostatic hypotension, carotid sinus hypersensitivity, vasovagal/situational syncope, and cardiac arrhythmias. In practice, for lack of a thoughtful diagnostic strategy, many syncopal episodes remain unexplained. The initial clinical assessment is essential to make the diagnosis. It includes a comprehensive medical history, preferably with an eyewitness account, a thorough physical examination including supine and standing blood pressure measurements, and an electrocardiogram. After this initial step, carotid massage must be performed unless contraindicated because carotid sinus hypersensitivity is a frequent syndrome in the elderly. In the absence of an established diagnosis, the decision for further investigation depends on whether there is evidence of underlying heart disease. When heart disease is present or suspected, cardiac investigations are recommended. When heart disease is absent, a cardiac cause is unlikely and evaluation for neurally mediated syndromes is recommended in case of recurrent or severe syncope. Treatment depends on the etiology.

Definition

Syncope is defined as a sudden, transient, self-limited loss of consciousness associated with the inability to maintain postural tone, usually leading to falling.

Loss of consciousness may occur with or without premonitory symptoms (e.g., lightheadedness, nausea, sweating, weakness, and visual disturbances). The onset of syncope is relatively rapid. Although the duration of syncope is rarely accurately estimated, typical syncopal episodes are generally brief and shorter than 20 s. The subsequent recovery is spontaneous, usually rapid, and complete with restoration of appropriate behavior and orientation. In older persons retrograde amnesia is not uncommon.

Presyncope or near-syncope refers to a condition in which patients feel as though syncope is imminent. Symptoms associated with presyncope may be relatively non-specific (e.g., dizziness) and tend to overlap with those associated with the premonitory phase of true syncope. Syncope and presyncope share the same etiologies.

Classification and Main Etiologies in Older Persons

The principal groups of causes of syncope are the following:

1. Neurally mediated syncopes
2. Orthostatic and postprandial hypotensions
3. Cardiac causes: arrhythmias and mechanical causes
4. Cerebrovascular, psychiatric, and metabolic disorders.

Main etiologies of syncope in the older persons are listed in **Table 1**.

Studies have shown that, in older persons, the commonest causes of syncope are orthostatic hypotension, carotid sinus hypersensitivity, vasovagal/situational syncope, and cardiac arrhythmias. However, the prevalence of each cause varies widely from one study to another. Reasons for variability include aggressiveness of diagnostic evaluation, diagnostic criteria for causes, patient populations (e.g., all patients, emergency room visits, hospitalized patients),

Table 1 Main causes of syncope in the elderly

Neurally mediated syncopes	• Vasovagal syncope • Carotid sinus hypersensitivity • Situational syncope • Micturition • Defecation • Cough
Orthostatic and postprandial hypotensions	• Orthostatic hypotension • Autonomic failure • Primary autonomic failure syndromes (e.g., pure autonomic failure, multiple system atrophy, Parkinson's disease with autonomic failure) • Secondary autonomic failure syndromes (e.g., diabetic neuropathy, amyloid neuropathy) • Drug (and alcohol)-induced orthostatic syncope • Volume depletion • Hemorrhage, diarrhea, Addison's disease • Postprandial hypotension
Electrical cardiac causes	• Sinus node disease • Second- or third-degree heart block • Pacemaker malfunction • Drug-induced proarrythmias • Ventricular tachycardia • Torsade de pointes • Supraventricular tachycardia
Mechanical cardiac causes	• Aortic stenosis • Hypertrophic cardiomyopathy • Pulmonary embolism
Neurological causes	Rare
Psychiatric causes	Rare
Metabolic causes	Rare

and whether patients with a likely seizure disorder were included or not.

In older frail patients, coexisting illnesses and medications may interact to cause syncope.

Neurally Mediated Syncopes

The neurally mediated syncopes encompass a number of disorders including vasovagal syncope, situational syncope, and carotid sinus hypersensitivity. Although the precise mechanism is poorly understood, these syndromes are believed to result from an exaggerated cardiac and neurocardiac reflex that leads to acute vasodilatation of the arterial and venous beds and relative or absolute bradycardia. The triggering factors for neurally mediated syncope are various, including orthostatic stress, emotional stress, urination, coughing, swallowing, physical exercise, and stimulation of the carotid sinus in susceptible persons.

Vasovagal Syncope Vasovagal syncope is the most common cause of fainting in both children and young adults. It is less frequent in older persons.

Although the underlying mechanism of vasovagal syncope is not totally understood, it is believed that the venous pooling in the lower extremities while in an upright position is the trigger mechanism. This shift in blood volume can markedly decrease the cardiac output that is sensed by arterial baroreceptors located in the aortic arch and carotid sinus. These receptors transmit signals to the nervous system and result in reflex-increased sympathetic output with increased heart rate and hypercontractility. In addition, the vascular system responds locally by restricting blood flow to non-vital organs such as the skin, muscles, and adipose tissue, thereby enhancing peripheral resistance. Cardiac mechanoreceptors found in ventricles, atria, and pulmonary artery, which are usually activated by distension of the heart, undergo abnormal stimulation that is believed to result from the combined hypercontractility and emptiness of the ventricle. The afferent fibers (unmyelinated C fibers) project abnormal mechanoreceptor stimulation centrally to the brain stem (tractus nucleus solitarius and other centers). The efferent part of the reflex results in parasympathetic stimulation leading to vasodilation (vasodepressor effect) and sympathetic withdrawal leading to bradycardia (cardioinhibitory effect) with ensuing syncope. In addition, several neuroendocrine changes are observed during orthostatic stress. At the time of syncope, a higher level of epinephrine and a decreased renin activity is found in patients with neurally mediated syncope. In the case of the emotionally induced vasovagal faint, higher cortical sites are believed to be the predominant triggers of the afferent limb of the reflex arc.

Typically, loss of consciousness in vasovagal syncope occurs in the upright position and is preceded by prodroma such as nausea, warmth, diaphoresis, lightheadedness, blurred vision, headaches, palpitations, paresthesia, and pallor. Prodroma may last from less than 1 s to several minutes. Occasional patients may not exhibit any symptoms at all. The recovery is almost immediate when the patient assumes the supine position. After recovery, patients may complain of a washed-out and tired feeling. When necessary, the diagnosis can be confirmed by a tilt table test that is the diagnostic technique of choice for clinically assessing susceptibility to neurally mediated syncope, particularly of the vasovagal type.

Treatment strategies for vasovagal syncope remain controversial. Many single episodes do not warrant treatment unless physical injury has occurred or a high-risk occupation or avocation is involved. Patients should be principally assured of the condition's benign nature, informed of the likelihood of syncope recurrence, and educated to recognize warning signs of an imminent faint and to avoid situations that predispose to syncope. Chronic vasodilator treatments must be discontinued when possible because they have been shown to enhance susceptibility to vasovagal syncope.

Because no single large, randomized study has been undertaken to test the efficacy of pharmacological therapy (e.g., beta-adrenergic blockers, disopyramide, serotonin reuptake blockers, theophylline, fludrocortisone, ephedrine, etilephrine, midodrine, clonidine) or pacing therapy, therapeutic strategy is not well defined. Therapy is guided by symptom recurrence and the benefit/risk ratio. If symptoms are severe, recurrent, and refractory to medical treatment, with a documented bradyarrhythmia, pacemaker implantation may be considered.

Situational Syncope Situational syncope refers to those forms of neurally mediated syncope that occur after cough, defecation, and micturition or associated with throat or facial pain (glossopharyngeal or trigeminal neuralgia). In situational syncope, the activation of peripheral receptors in the bladder, the esophagus, and the respiratory tract similar to ventricular mechanical receptors may lead to a reflex increase in vagal efferent activity and sympathetic withdrawal. In these conditions, it may be impossible to avoid exposure to the trigger. Other treatment strategies may be advocated, including maintenance of central volume, protected posture (e.g., sitting rather than standing), slower changes of posture

(e.g., waiting after a bowel movement before arising), avoidance of excessive fluid intake (especially alcohol) just prior to bedtime in postmicturition syncope, and elimination of excessive cold drinks or large boluses of food in swallow syncope.

Carotid Sinus Hypersensitivity Carotid sinus hypersensitivity, also called carotid sinus syndrome, is an underrecognized cause of recurrent unexplained syncope and of recurrent falls in the elderly. When carotid sinus massage is systematically performed, carotid sinus hypersensitivity is diagnosed in approximately 20% of older people who presented with unexplained syncope. The prevalence of carotid sinus hypersensitivity increases with advancing age and with cardiovascular, cerebrovascular, and neurodegenerative comorbidity. Studies have shown that 5–25% of asymptomatic older men have carotid sinus hypersensitivity. At the same time, only 5–20% of patients showing carotid sinus hypersensitivity actually have syncope of carotid sinus origin.

Diagnosis of carotid sinus syncope requires that spontaneous symptoms of presyncope or syncope be reproduced by carotid sinus massage. Normal response to the external stimulation of the carotid sinus consists of slowing of the sinus rate and impaired atrioventricular node conduction. In carotid sinus hypersensitivity this reflex is exaggerated. The underlying mechanisms that lead to this hypersensitivity of the carotid sinus remain debated.

Clinical presentation may be typical when syncope occurs with rotation or turning of the head or pressure on the carotid sinus (for example, carotid massage, shaving, tight collars or neckwear, or tumor compression). A previous neck surgery reinforces the diagnosis. More often, recurrent unexplained syncope and unexplained falls are the clinical presentation of patients with carotid sinus hypersensitivity without a specific trigger.

Carotid sinus massage is contraindicated in patients with the presence of a carotid bruit, stroke, or myocardial infarction within the previous 6 months, or a history of ventricular tachycardia or ventricular fibrillation. Carotid sinus massage is performed by applying longitudinal digital pressure at the bifurcation of the internal and external carotid artery or the area of greatest arterial pulsation for 5 s. Blood pressure and pulse rate must be monitored. A venous access is required. The right carotid sinus is stimulated first, followed by the left a few minutes later. Massage should be done in the supine position and, if negative, in the upright position, because in up to a third of patients a diagnostic cardioinhibitory response is only present when upright. With a good technique, complications are rare, ranging from visual disturbances to hemiplegia in rare cases, most of which are transient and result in full recovery. Carotid sinus hypersensitivity is defined as asystole of 3 s or more (cardioinhibitory form), or a fall in systolic pressure of 50 mmHg or more (vasodepressor form), or the association of both (mixed form) during carotid sinus massage. Carotid sinus syndrome of predominantly vasodepressor form is probably as prevalent as cardioinhibitory form, but its potential role in causing syncope is much less certain.

Available information indicates that pacing may have a strong beneficial effect and prevents recurrence of syncope in patients with cardioinhibitory form. A variety of medical therapies has been used with unclear effects in vasodepressor form. Recently, a pilot study of crossover design in 10 older adults with a history of unexplained syncope and vasodepressor form of carotid sinus hypersensitivity has suggested that treatment of the vasodepressor form with midodrine significantly reduces the rate of symptom reporting and attenuates systolic blood pressure decrease after carotid sinus massage.

Orthostatic and Postprandial Hypotensions

Orthostatic Hypotension Orthostatic hypotension is a frequent blood pressure disorder in the elderly that has been shown to be an attributable cause of syncope in 20 to 30% of older patients.

Since the consensus meeting in 1996 of the American Autonomic Society and the American Academy of Neurology, orthostatic hypotension is defined as a drop in systolic blood pressure of $>$ or $=20$ mmHg and/or diastolic blood pressure of $>$ or $=10$ mmHg, 1, 2, or 3 min after the person moves from a supine to a sitting or standing position. In a volume-depleted patient, the heart rate should rise on standing. In a patient with dysautonomic syncope, the blood pressure can drop over several minutes while upright with no concomitant change in heart rate. Because the within-day and day-to-day intra-individual reproducibility of the diagnosis of orthostatic hypotension is poor, postural test should be repeated.

In orthostatic syncope, the triggering mechanism is the blood shift of 300 to 800 ml from the thorax to the lower extremities that occurs upon changing from a supine to an upright position. Following a change in posture to the upright position, baroreceptors provoke an increase in medullary sympathetic outflow. This leads to vasoconstriction of the systemic resistance vessels and the splanchnic capacitance vessels. Compensation for continued orthostatic stress depends principally on the arterial baroreceptors.

Orthostatic hypotension may be due to volume depletion and/or abnormal vasomotor compensatory mechanisms. Medications that alter vascular tone and heart rate increase the risk of orthostatic hypotension. Disorders of autonomic vasomotor control leading to orthostatic hypotension may be primary (pure autonomic failure and multiple system atrophy) or, more commonly, secondary to diabetic neuropathy or amyloidosis.

Older adults are predisposed to orthostatic hypotension because of the association of the blunted age-related autoregulatory mechanisms, medications (e.g., diuretics, vasodilators), chronic diseases (such as systolic hypertension, diabetes mellitus, Parkinson's disease), or frequent medical conditions in geriatrics (anemia, dehydration, bed rest). The prevalence of orthostatic hypotension increases with age but also varies according to the population being studied. A range of 5 to 60% has been reported, with the lower rate in vigorous old persons living in the community and higher rates in those living in an institution or in the acute care setting.

The treatment of orthostatic hypotension relies on non-pharmacological and pharmacological approaches: patient's education (avoiding sudden head-up postural change [especially on waking]; raising the head of the bed; physical countermaneuvers such as leg crossing and squatting; avoiding large meals, especially with alcohol; physical exercise, especially swimming), wearing of elastic stockings, reducing dosage or elimination of the responsible medication (diuretics, vasodilators, etc.), and, at a later stage, when non-pharmacological methods are unsuccessful, drug therapy. Fludrocortisone, a salt-retaining steroid, and midodrine, a sympathetic vasoconstrictor drug, are considered first and can be used in combination if necessary.

Postprandial Hypotension Over the past decade, postprandial hypotension, which is defined as a decrease in systolic blood pressure of 20 mmHg or more within 2 h of ingestion of a meal, has been recognized as a common cause of syncope and falls in the elderly. In one study, postprandial hypotension accounted for 8% of syncope cases in older nursing home patients. Postprandial hypotension can coexist with orthostatic hypotension in the same individual.

Although the precise pathophysiological mechanism is not fully understood, postprandial hypotension is probably the consequence of an alteration in the compensatory mechanisms for meal-induced splanchnic blood pooling and the lowering of peripheral vascular resistance following ingestion of food. A number of vasoactive gastrointestinal peptides have also been thought to play a role in the pathogenesis of postprandial hypotension since it has been established that the magnitude of the fall in blood pressure is related to the amount of glucose ingested during the meal and to the rate at which glucose enters the small intestine.

Treatment of postprandial hypotension, which may be non-pharmacological and pharmacological, is not well codified, because too few rigorous studies have been conducted on symptomatic patients. Large meals with refined carbohydrates, alcohol consumption, and drugs with vasodepressor properties should be avoided by the patients. In healthy older participants, it has been demonstrated that the magnitude of the blood pressure fall induced by intraduodenal glucose is attenuated by the concomitant absorption of guar.

Cardiac Causes

Cardiac syncope results from inadequate effective cardiac output and may reflect serious underlying structural heart disease. The causes may be electrical (arrhythmic) or mechanical (obstructive).

Cardiac Arrhythmias Cardiac arrhythmias are among the most common and potentially hazardous causes of syncope in patients with structural heart disease. Syncope from arrhythmias may result from ventricular tachycardia, supraventricular tachycardia, polymorphic ventricular tachycardia related to a long QT interval (torsade de pointes), bradyarrhythmias caused by sinus node dysfunction, or conduction system disease. Persistent or episodic high-grade atrioventicular block may result in sufficient loss of cardiac output to cause syncope.

The high prevalence of ischemic heart disease, cardiomyopathy, hypertension, valvular heart disease, and heart failure among the elderly predispose them to a broad range of tachyarrhythmias and bradyarrhythmias. An age-related fall in nodal myocytes, particularly in the sino-atrial node, increases the incidence of atrial fibrillation, heart block, and sick sinus syndrome. Polypharmacy in the elderly is another predisposing factor. Diuretics may cause electrolyte imbalance, which predisposes to arrhythmias. Many drugs have proarrhythmic effects such as digoxin, antiarrhythmic drugs, beta-2 agonist bronchodilators, and tricyclic antidepressants. Torsade de pointes in the setting of acquired prolonged QT interval is also typically associated with drugs including amiodarone, beta-blockers, neuroleptics, and class 1 anti-arrhythmic agents.

Mechanical Causes Main causes in the elderly are aortic stenosis and hypertrophic cardiomyopathy. In

these conditions, syncope is believed to be due to a combination of reduced cardiac output and neurally mediated reflex factors involving the ventricular mechanoreceptors. Vasodilator drugs or even vasodilatation after a hot bath can induce syncope in these patients.

Syncope also may be due to obstruction of the pulmonary artery secondary to pulmonary embolism. Syncope occurs in over 10% of patients with pulmonary embolism and is more likely to occur with massive embolism and in the elderly.

Other rare cardiac mechanical causes of syncope include atrial myxoma, severe mitral stenosis, prosthetic valve dysfunction, and pulmonary stenosis.

Cerebrovascular, Psychiatric, and Metabolic Causes

Syncope is rarely due to cerebrovascular disease in the absence of accompanying focal neurological deficits. Occasionally, transient ischemic attacks in the vertebrobasilar territory may cause syncope, but there are usually concurrent neurological symptoms including diplopia, vertigo, dysarthria, or hemiparesis.

Vascular steal syndromes are rare cerebrovascular causes of syncope in the elderly.

Psychiatric disturbances including hysterical reaction and panic attack with hyperventilation can either mimic or may lead to true syncope. But psychiatric causes of syncope are relatively rare in the elderly.

Metabolic disturbances are relatively infrequent causes of true loss of consciousness. More often these disturbances are responsible for confusional states or behavioral problems.

Epidemiology and Prognosis

Syncope accounts for 1–6% of visits to emergency departments in Europe and in the United States and 1–5% of all admissions to hospital. Elders and patients with associated cardiovascular diagnoses are admitted more frequently. In a large epidemiological study in the United States, 58% of patients older than 80 years of age with syncope presenting to emergency departments were admitted. In one study, syncope and collapse were the sixth most common reason for admission of adults aged over 65 years to acute medical hospital beds.

The prevalence of syncope increases with advancing age, ranging from 15% in children under 18 years to 23% in elderly patients over 70. Furthermore, data in the elderly are probably underestimates because of the exclusion of syncopal episodes that present as falls. The highest frequency of syncope occurs in patients with cardiovascular comorbidity and older patients in institutional care settings. In a study, among elderly persons living in long-term care institutions, annual incidence of syncope was as high as 6%, 10 times greater than the incidence observed in the Framingham Heart Study population.

Other important risks associated with recurrent syncope in the elderly are the fracture risk linked to falls and the risk of progressive restriction of activity due to the loss of confidence, leading to the inability to live alone.

In a recent study in the United States, a nationally representative sample of hospital discharges and reported charges was analyzed, and costs were estimated using Medicare cost-to-charge ratios. A conservative estimate of total annual costs for syncope-related hospitalizations was $2.4 billion, with a mean cost of $5400 per hospitalization.

The prognosis is dependent on the cause of syncope. Several population-based studies have shown that persons with cardiac syncope are at increased risk for death from any cause and cardiovascular events as compared with patients with non-cardiac syncope. In the Framingham Heart Study, among 822 syncopes in 7814 participants, the most frequently identified causes were vasovagal (21.2%), cardiac (9.5%), and orthostatic (9.4%); for 36.6% the cause was unknown. The multivariable-adjusted hazard ratios among participants with cardiac syncope, as compared with those who did not have syncope, were 2.01 (CI 95%: 1.48 to 2.73) for death from any cause, 2.66 (CI 95%: 1.69 to 4.19) for myocardial infarction or death from coronary heart disease, and 2.01 (CI 95%: 1.06 to 3.80) for fatal or non-fatal stroke. Participants with syncope of unknown cause and those with neurological syncope had increased risks of death from any cause, with multivariable-adjusted hazard ratios of 1.32 (CI 95%: 1.09 to 1.60) and 1.54 (CI 95%: 1.12 to 2.12), respectively. There was no increased risk of cardiovascular morbidity or mortality associated with vasovagal (including orthostatic and medication-related) syncope.

However, the higher mortality observed in the population with cardiac syncope is largely due to the underlying cardiac disease, irrespective of the precise cause of syncope. Indeed, a study comparing patients with and without syncope matched for cardiac disease and other important clinical variables found that cardiac syncope was not a significant predictor of overall or cardiac 1-year survival.

Pathophysiology

Although causes of syncope are multiple, the underlying mechanism is unique; syncope is the consequence

of a transient global decrease of cerebral blood flow. Cerebral vascular autoregulation ensures that the cerebral blood flow is maintained within a large range of systemic blood pressure. In elderly people, especially in those with chronic hypertension, cerebral vascular autoregulation system is altered, leading to an increased incidence of syncope in this population. A number of other factors increase the risk of developing syncope among the elderly, such as age-related physiological changes in heart function, blood pressure, baroreflex sensitivity, intravascular volume regulation, comorbid conditions, and concurrent medications. The main age-related physiological changes that predispose to syncope are listed in **Table 2**.

Clinical Approach

The main goals in the management of the patient with syncope are the following:

- To establish whether the patient had syncope or not
- To determine the cause of syncope
- To decide whether the patient needs to be hospitalized
- To treat the causes of syncope.

Table 2 Main age-related physiological changes that predispose to syncope

Blood vessels	• Impaired endothelial (NO)-dependent vasorelaxation • Increased endothelin release in the aging vessels, promoting vasoconstriction
Heart	• Age-related stiffening of arterial vessels leading to increased afterload pressures and cardiac concentric hypertrophy • Subsequent alteration in ventricular walls compliance and in diastolic function • Age alterations of nodal tissue, increasing the incidence of atrial fibrillation, heart block, and sick sinus syndrome • Atrial dilatation and fibrosis, increasing the risk of atrial fibrillation
Autonomic nervous system	• Diminished beta-adrenergic responses leading to reduced cardioacceleration • Altered baroreflex responsiveness
Endocrinal changes	• Impaired renin and aldosterone production • Impaired thirst response contributing to hypovolemia

Diagnostic and Management Strategy

Because syncope is a symptom, not a disease, identification of the cause is essential for successful management. Ordinarily, the evaluation and treatment of patients with syncope often do not rely on an appropriate well-defined management strategy. The consequences are multiple: too many useless diagnostic tests, too many hospital admissions, increased costs, and too many patients in whom the diagnosis remains undetermined.

In the older patients, particularly, the identification of the cause must be difficult because of multiple potentially causal factors, amnesia of the episode, lack of witness, overlap with falls, and additional cognitive impairment.

Several guidelines have been published for the diagnostic approach to patients with syncope. None has been validated prospectively. However, it has been demonstrated that the use of a diagnostic algorithm, especially in the setting of syncope units, may improve significantly the use of appropriate investigations, reduce the number of syncope remaining without a defined etiology at discharge, and reduce the number of hospital admissions and total length of hospital stay without affecting recurrent syncope and all-cause mortality.

The European Society of Cardiology published in 2001 high-quality guidelines for the management (diagnosis and treatment) of syncope, and in 2004, an update of the text. Important recommendations of this guideline include the following:

- A detailed history, physical examination, and an electrocardiogram (ECG) are the components of the initial evaluation of a syncopal episode. This first step may lead to a diagnosis (e.g., orthostatic hypotension, situational syncope, drug-induced syncope, complete atrioventricular block) or suggest a diagnosis that can be confirmed or excluded with directed investigations. If the diagnosis is not confirmed, these patients are approached as unexplained syncope.
- After the initial evaluation, when syncope remains unexplained, in the absence of contraindications, a carotid sinus massage should be performed in all elderly persons, given the high prevalence of carotid sinus syndrome as a cause of syncope in this age group.
- The decision for further diagnostic tests depends on whether there is evidence of underlying structural heart disease (**Figure 1**). In the young adult, clinical evaluation (history, physical examination, and ECG) is sufficient to identify or exclude the presence of heart disease. In older persons, given

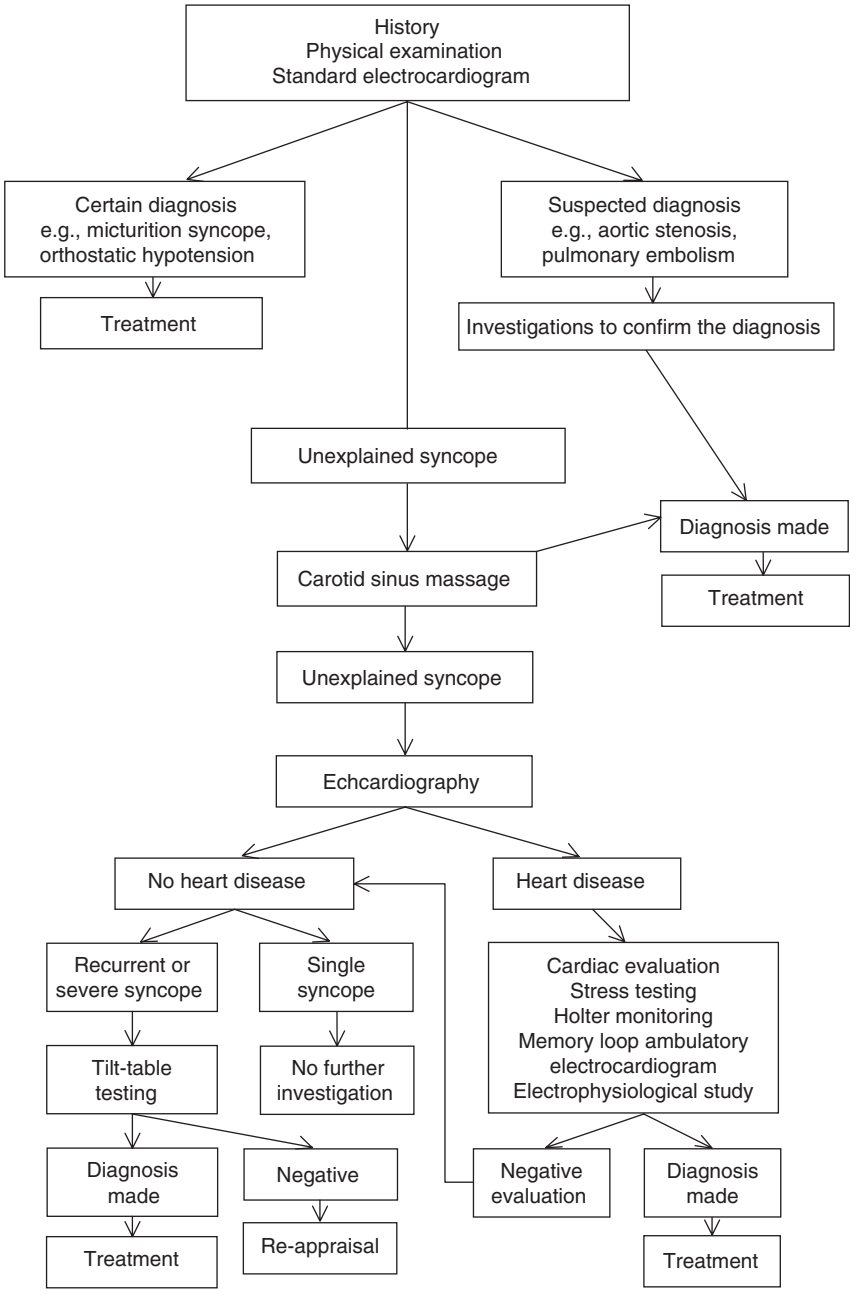

Figure 1 Diagnostic algorithm for syncope.

the high prevalence of cardiac diseases, an echocardiogram, a stress testing, or both are recommended to determine the presence or absence of underlying cardiac disease. But this question has not been addressed by valuable studies.

- The presence of heart disease is a strong predictor of cardiac cause of syncope. Consequently, patients who have evidence or suspicion of organic heart disease are at much higher risk for bad outcomes associated with syncope, with a higher risk of arrhythmias and a higher mortality at 1 year. In these patients, cardiac evaluation (consisting of echocardiography, stress testing, and tests for arrhythmia detection such as Holter monitoring and memory loop ambulatory ECG, and electrophysiological study) is recommended.
- When heart disease is absent, a cardiac cause is unlikely unless syncope is preceded by palpitations, which could be due to paroxysmal tachycardia. In the other cases, evaluation for neurally mediated syndromes by a tilt table test is recommended in those with recurrent or severe syncope.
- Generally, a cause of syncope can only be concluded if there is a sufficiently strong correlation

between syncopal symptoms and the detected abnormalities on investigations.

- In vigorous older patients with syncope, the clinical approach and the assessment are the same as for younger adults, with the exception of routine carotid sinus massage. In frailer older adults, evaluation should be modified according to functional status, prognosis, and compliance with tests. When multiple abnormalities are identified, they should be treated with the presumption that the syncope may be multifactorial.
- If the evaluation remains negative, the entire approach should be reappraised. Reevaluation may include the retaking of a history and the interviewing of witnesses to obtain more additional information. Close follow-up of patients with syncope of unknown cause is recommended, and a complete reassessment should be undertaken if the patient has recurrences.
- While most younger patients (without heart disease) can be effectively evaluated and managed as outpatients, a majority of older patients with syncope must be hospitalized:
  - for a rapid diagnostic evaluation in the presence of a known or suspected heart disease because of concerns about serious arrhythmias and sudden death
  - for the treatment of the cause when this treatment requires hospital admission (e.g., pulmonary embolism or severe orthostatic hypotension).
- The goals of the treatment of patients with syncope are, first, the prevention of symptom recurrence and associated injuries, and, second, the improvement of quality of life. Treatment (discussed earlier) depends on the underlying cause of the symptom.

Initial Evaluation

History A detailed account of the associated symptoms and the symptoms preceding and following the loss of consciousness is crucial to the diagnosis. These events and symptoms were described in detail previously for each cause of syncope and are summarized in **Table 3**. In addition to the history given by the patient, information available from a witness of the event is very important because of the problem of frequent amnesia of the episode in older adults.

Past medical history, especially of cardiac diseases and non-cardiac diseases or risk factors that increase the likelihood of cardiovascular syncope (diabetes, anemia, hypertension), must be recorded.

The history should include details of medication use, in particular, changes in medication. Usually, the differential diagnosis between syncope and non-syncopal disorders (**Table 4**) is rather easy. However, epilepsy may be difficult to distinguish from syncope. Features that help to distinguish syncope and epilepsy are the precipitants of the episode, the prodromal symptoms, the symptoms that accompany the episode, and the events that follow it. The presence of confusion after the event is the single most powerful discriminator between seizure and syncope.

Loss of consciousness precipitated by pain, exercise, micturition, defecation, or stressful events is generally due to syncope. Aura such as typical unpleasant smell may precede a seizure. Aura patterns are usually repetitive over time in patients, who will therefore learn to recognize them as such. Symptoms

Table 3 Events preceding and following the loss of consciousness

Cause of Syncope	*Prodromal symptoms*	*Situations and precipitating factors*	*Symptoms following the loss of consciousness*
Neurally mediated syncope	Nausea, pallor, diaphoresis, visual blurring, light headedness, hearing loss, weakness	Neck turning, stressful or emotional situations, pain, fear, crowding, prolonged upright posture, cough, micturition, swallowing, defecation	Lack of postsyncope drowsiness
Cardiac syncope	Sudden onset, effort, or exertion, preceding chest pain, palpitations	Drug-related arrhythmia: anti-arrhythmics, neuroleptics, digoxin, beta-blockers, alcohol, illicit drugs	Rapid resolution of symptoms
Orthostatic hypotension	Abrupt changes in posture	Drug-related: angiotensin converting enzyme (ACE) inhibitors, nitrates, diuretics, alcohol	

Table 4 Non-syncopal disorders from which syncope or pre-syncope must be distinguished

Non-syncopal disorders with impairment or loss of consciousness	• Metabolic disorders, including hypoglycemia, hypoxia, hyperventilation with hypocapnia ○ Epilepsy ○ Intoxications ○ Vertebro-basilar transient ischemic attack
Non-syncopal disorders without loss of consciousness	• Cataplexy • Drop attacks • Vertigo • Psychogenic syncope (somatization disorders)

such as sweating, nausea, and vomiting before or after the event are associated with syncope. A long duration of loss of consciousness ($\geqslant 5$ min), aching muscle, tongue biting, and prolonged confusion after the event suggest a seizure. Urinary incontinence is not useful in the distinction. Witnesses should be asked to describe any movements. A loss of consciousness without any movement makes epilepsy unlikely, and rhythmic movements (such as clonic or myoclonic jerks) suggest seizure. However, movements do not exclude the diagnosis of syncope. In syncope, tonic-clonic movements are always of short duration (<15 s) and they start after the loss of consciousness, while in epilepsy, tonic-clonic movements are usually prolonged and their onset coincides with loss of consciousness.

Physical Examination The physical examination includes a search for trauma and assessment of severity. Cardiovascular examination may give some clues about the presence or absence of an underlying cardiac or pulmonary pathology. Blood pressure and pulse measurements should be taken both in the supine and standing positions. Special attention also should be paid to neurological signs and locomotor systems, including observation of gait and standing. If cognitive impairment is suspected, this should be formally determined. The Mini Mental State Examination is a useful tool for the initial evaluation of the cognitive status.

Electrocardiogram Electrocardiogram is recommended in all elderly patients. It is commonly abnormal, revealing, for example, sinus node dysfunction, tachycardia–bradycardia syndrome, or abnormal conduction (prolonged PR interval, bundle-branch block), old myocardial infarction, or ventricular hypertrophy. But in most patients, ECG is not diagnostic (in less than 5% of patients). However, a normal ECG reduces the likelihood of cardiac syncope.

Current Investigations Used to Assess Syncope

Echocardiography Echocardiography is a non-invasive test that is well tolerated even by frail elderly patients. When a cardiac disease is suspected due to history, physical examination, or ECG, the echocardiography can be very useful to identify potential causes of cardiac syncope. In the elderly, echocardiography is essential to exclude the presence of a structural heart disease. Echocardiography reveals frequently unsuspected abnormalities such as left ventricular global and regional wall dysfunction, dilated or hypertrophic cardiomyopathy, and aortic and mitral valve disease, all of which predispose the patient to arrhythmias and cardiogenic syncope. However, the discovery of such abnormalities does not necessarily lead to the diagnosis of a cause.

Exercise Stress Testing Exercise stress testing is principally useful in patients who experience syncope on exertion. The test should be closely monitored during the exercise and recovery phases. It can reveal catecholamine-sensitive ventricular tachycardia, rate-dependent atrioventricular block, or exercise induced neurally mediated syncope.

Ambulatory Continuous Electrocardiography In patients with structural heart disease or abnormal ECG, arrhythmias are the major concern. Holter monitoring and memory loop ambulatory ECG recording are used in the evaluation of these patients.

Because Holter monitoring allows recording of ECG during 24 h, it is most useful in patients with multiple or frequent episodes of syncope over a short period of time. When typical symptoms occur while the ECG is being recorded, it either identifies the arrhythmia causing the syncope or excludes arrhythmia as a cause of the symptoms. However, this situation is very rare. Extending the recording to 72 h did not increase dramatically the yield for symptomatic arrhythmias. A normal Holter monitoring without symptoms does not exclude the possibility that the syncope is due to an arrhythmia. The interpretation of an arrhythmia without associated symptoms must be cautious because a wide range of arrhythmias have been reported in healthy asymptomatic individuals. However, complete heart block, sinus pauses of more than 2 s, and ventricular tachycardia are rarely reported in asymptomatic patients.

Memory loop ambulatory ECG recording is more useful than Holter monitoring in patients with infrequent symptoms. The memory loop recorders allow

the recorded ECG data to be stored. The device is worn continuously. When the patient activates the device, an ECG recording from 1 to 4 min before and 30–60 s following pressing the recording button is obtained. The data can be transmitted over the telephone at the patient's convenience. Unfortunately, many older patients are not compliant, and up to 20% of patients do not wear or operate the device appropriately.

The most recent development in this technology is a small implantable loop recorder (ILR) (Reveal; Medtronic, Minneapolis, USA). The device is placed subcutaneously. The compliance is better with this system. The device continuously records the ECG into its looping memory for up to 18 months. An external activation device is used at the time of symptoms. The device stores ECG data 20 min before and 4 min after activation. However, a small proportion of patients are unable to activate the device after a spontaneous event. In a study, it has been reported that the use of these devices established a symptom–arrhythmia correlation in 42% of the 85 patients who had recurrence of symptoms within 3 months of implant.

Invasive Electrophysiological Studies Invasive electrophysiological studies allow the measurement of conduction times between specific cardiac sites. They provide information about sinus node function, atrio-ventricular conduction, and ventricular conduction, thus determining the predisposition to abnormalities of cardiac conduction. Use of electrical extrastimuli coupled to normal sinus rhythm or paced rhythms can be used to evaluate the propensity for developing tachyarrhythmias and allow analysis of the mechanism of arrhythmias. The yield of electrophysiological tests depends on whether there is heart disease; the results are more likely to be positive in the patients with structural heart disease, especially those with an ejection fraction less than 40%. Generally, electrophysiological studies have poor sensitivity and specificity in patients with bradyarrhythmias associated with syncope. Loop monitoring is the test of choice when bradyarrhythmia is a consideration. Syncope can be attributed more confidently to abnormalities of His-Purkinje conduction. Syncope associated with induced or spontaneous ventricular tachyarrhythmias on electrophysiological testing is accompanied by a high risk of death. Induction of sustained monomorphic ventricular tachycardia (lasting > 30 s) in a patient who has experienced syncope makes this arrhythmia the likely cause of the syncopal episode. A negative stimulation response does not exclude a ventricular arrhythmia as the cause of the patient's previous symptoms. Cardiac arrest survivors with poor left ventricular function and negative electrophysiological studies have rates of sudden death of up to 30% at 1 year.

Tilt Table Testing Tilt table testing, also named head-up tilt table testing, is a non-invasive provocative test used to determine a patient's susceptibility to neurally mediated syncope. As demonstrated by a large prospective study including 1096 subjects aged 60 to 74 and 873 aged 75 and older, tilt table testing is a safe and well-tolerated investigation in older people with one cardiovascular and no neurological complications.

Tilt table testing is best considered for patients with suspected neurally mediated syncope but in whom the cause is not obvious or in patients with syncope of otherwise unknown origin with no evidence of structural heart disease. Because the symptoms, the hemodynamic responses, and the release of catecholamines during tilt table testing are similar to those during spontaneous vasovagal syncope, tilt table testing is believed to provoke vasovagal syncope in susceptible persons.

During the test, the patient should be in a fasting state, blood pressure and electrocardiographic monitoring should be continuous, and resuscitative equipment should be available. The head of the table is tilted upward to an angle of 60 to 80°, with 70° most commonly used. The test is continued for 30 to 45 min unless hemodynamic collapse occurs earlier. If the drug-free test is negative, a provocative agent such as nitroglycerin or isoproterenol is administered, and tilting is continued for another 10 to 15 min. Sublingual nitroglycerine use with tilt table testing seems to be simpler and better tolerated, especially in the elderly and in those with coronary artery disease.

The result is considered positive for vasovagal syncope if the original symptoms are reproduced with objective evidence of an abrupt blood pressure decrease or bradycardia (or both). Patients with a dysautonomic response to tilt table testing demonstrate a gradual and progressive decrease in blood pressure with only a small or no significant change in heart rate.

Most studies suggest that such testing discriminates relatively well between symptomatic patients and asymptomatic control subjects. However, 10 to 15% of asymptomatic subjects have false-positive test results. Sensitivity of tilt table testing is more difficult to evaluate because there is no accepted diagnostic gold standard. It has been calculated at between 20 and 75%. Pharmacological provocation

increases the sensitivity of the test while the specificity decreases a little.

Neurological Investigations and Laboratory Tests In the absence of focal neurological deficits, and symptoms or a history suggestive of transient cerebral ischemia or seizure, computed tomographic scans of the head, electroencephalography, and carotid echo-Doppler have very low yield and should not be performed in patients with syncope.

Baseline laboratory tests (for electrolytes, renal function, blood sugar, and hemoglobin) rarely lead to an assignment of cause (in 2 to 3% of patients) but may reveal predisposing factors for various causes of syncope such as anemia or hypokaliemia.

Conclusion

Syncope and presyncope are great diagnostic challenges in geriatrics. Potential causes are multiple and the symptoms may result from a benign condition or from a serious cardiac disease that poses an imminent threat to life. Patients with a cardiac cause of syncope are at far greater risk of dying in the first year following the syncope than individuals with a non-cardiac cause. That is why the presence of a known or suspected heart disease helps to categorize patients into those with a high likelihood of cardiac syncope and those with a low likelihood. Cardiac evaluation is recommended in those patients with heart disease. In any case, a well-defined diagnostic strategy, in which the initial clinical evaluation is crucial, is needed to unmask the cause.

See also: Cardiovascular System; Falls; Frail Elderly.

Further Reading

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Telomeres

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Glossary

Hayflick Limit – The number of cell divisions that define a cell's replicative capacity.

Replicative Senescence – A deleterious cellular phenotype acquired at the end of a cell's replicative capacity.

Telomerase – A ribonucleoprotein complex that displays reverse transcriptase activity that is capable of extending telomeres via the addition of telomere repeat units.

Telomere – Genetic elements located at the ends of linear eukaryotic chromosomes, composed of a repetitive DNA sequence and associated protein complexes.

Introduction

Telomeres are essential chromosomal structures that cap the ends of linear eukaryotic chromosomes. Incomplete DNA replication every time cells divide results in a gradual loss of telomeric sequences in human somatic tissues. Telomere erosion ultimately results in the loss of telomeric function, which in turn triggers the cells to enter a non-dividing but biochemically active state termed replicative senescence. Telomere-dependent replicative senescence is considered to have evolved as a tumor suppressive mechanism; indeed, 85% of human malignancies express the enzyme telomerase that synthesizes telomere repeat sequences, preventing telomere loss and facilitating unlimited cell division. Senescent cells have the potential to interfere with the tissue microenvironment, and the accumulation of senescent cells is considered to contribute to age-related tissue deterioration and disease. Consistent with this hypothesis, telomere loss is observed as a function of age in human tissue, and this loss has been linked to specific disease phenotypes.

Replicative Senescence and Aging

The observation that normal human fibroblast cells display a limited life span in culture was first described by Hayflick in the 1960s. This phenomenon appeared to result from an intrinsic ability of the cell to count not chronological time, but the number of cell divisions they have undergone. Indeed, quiescent or frozen cells, once allowed to resume growth, still undertake the same number of divisions as if they had been grown continuously, i.e., they appear to remember the number of divisions they had undergone prior to freezing. After a number of cell divisions specific to each strain, referred to as the Hayflick limit, the cells enter a state of irreversible growth arrest referred to as replicative senescence. Typically around 50–100 population doublings, the Hayflick limit varies between different individuals and biopsy sites. Despite this variation, there appears to be a general trend toward a decrease in the limit as a function of age, which may reflect the replicative history of the cells *in vivo*. Since the initial observations in fibroblast strains, many other human somatic cell types, including lymphocytes, astrocytes, endothelial cells, epithelial cells, and myocytes, have been shown to undergo replicative senescence. Senescent cells remain biologically active but display a change in their gene expression profile to a more catabolic and pro-inflammatory phenotype. For example, senescent cells upregulate specific matrix metalloproteinases (such as collagenase) and downregulate their corresponding tissue inhibitors; such a phenotype has been demonstrated to actively degrade the tissue microenvironment. Furthermore, senescent stromal fibroblasts can specifically stimulate the proliferation of premalignant epithelial cells in a manner similar to that described for carcinoma-associated fibroblasts. Thus, in addition to the simple cessation of cell division, an age-related accumulation of senescent cells has the potential to disrupt tissue homeostasis and

underlie age-related disease and cancer (*see* Cellular Aging: Growth Factors and Cellular Senescence).

Telomeric Functions and Structure

In the 1920s Herman Muller observed that after X-irradiation, *Drosophila* chromosomes have various types of internal rearrangements, including translocations, inversions, and deletions; however, no rearrangements that involved the ends of chromosomes were detected. Thus, he proposed the existence of an essential structure at the ends of chromosomes that was necessary to maintain chromosomal integrity. He named these structures telomeres, meaning end parts. In the 1930s, Barbara McClintock, working on chromosomes in the endosperm of maize, observed the effects of losing telomeric functions; dicentric chromosomes were observed to undergo anaphase bridging, resulting in chromosome breakage and further cycles of fusion, bridge, and breakage. However, these cycles did not continue indefinitely, as in embryonic tissue she described chromosome healing whereby the broken ends were no longer fusagenic and behaved like natural chromosome ends. Thus, telomeres were demonstrated to be specialized structures that cap the ends of chromosomes and prevent end-to-end fusion. The molecular structure of telomeres was not established until 1978 when Elizabeth Blackburn was sequencing the rRNA genes in *Tetrahymena*. The genome of *Tetrahymena* contains tens of thousands of linear DNA molecules containing amplified genes; Blackburn discovered that the rRNA genes terminated in tandem arrays of the hexameric sequence TTGGGG. Within 10 years of this discovery, related simple sequence elements were discovered at the chromosome ends of the majority of eukaryotes. In 1988 the human telomeric sequence was established to be TTAGGG reiterated into arrays of 5–20 kb.

After the mechanisms of DNA replication had been elucidated, a potential additional role for telomeres was proposed by Alexey Olovnikov in 1971 and independently by Watson in 1972. Olovnikov pointed out a problem that would arise when linear DNA was replicated by semiconservative replication initiated from RNA primers. When the replication fork reaches the end of the chromosome, the continuous strand will be synthesized 5′ to 3′ of the end of the molecule, creating a fully replicated chromosome. However, the discontinuous or lagging strand that is synthesized in discrete units (Okazaki fragments) each initiated from an RNA primer could not be fully replicated. Even if the last RNA primer was located at the end of the molecule, once removed there would a gap at least as long as an RNA primer and potentially up to the length of an Okazaki fragment (**Figure 1**). The outcome of this would be a gradual shortening of the telomere with each round of replication. Showing remarkable insight, Olovnikov pointed out that this could create a cell division counting mechanism that had the potential to account for replicative senescence.

The answer to Olovnikov's end replication problem came again from *Tetrahymena*. It had been noted that plasmids containing *Tetrahymena* telomere repeats could function as telomeres in yeast via the addition of yeast telomere repeats onto the end of the *Tetrahymena* repeats. Thus, the existence of a terminal transferase activity was postulated, and the abundant telomeres of *Tetrahymena* rendered this organism a good source of this activity, which was subsequently purified by Greider and Blackburn in 1985. Further work established that this activity was a reverse transcriptase with a RNA component that templated the addition of telomere repeats on to the 3′-OH of the terminus; the enzyme complex was termed telomerase.

In humans the G-rich telomeric DNA strand is orientated 5′ to 3′ toward the terminus, and the terminus is composed of a 3′ overhang of several hundred bases in length. It is now established that human telomeres are composed of a nucleoprotein complex that folds back on itself to form a lariat structure termed a T loop that may be facilitated in part by strand invasion of the 3′ overhang into the beginning of the telomere repeat array. This T loop may mediate some of the functions of telomeres by sequestering away the terminus such that it is not available for fusion. A complex set of proteins have been identified that together form functional telomeres. These proteins are assembled to two major complexes formed around the telomere repeat binding factors TRF1 and TRF2 that in dimeric form directly bind TTAGGG repeats. Numerous proteins have been identified on the basis of their interaction with these two proteins. A key role of the TRF1 complex is in the regulation of telomere length via a telomere repeat counting mechanism that regulates the access of telomerase to the terminus, thus creating a negative feedback loop. Consistent with this concept, the overexpression of TRF1 in telomerase-expressing cells results in telomere shortening, whereas a dominant negative TRF1 that inhibited the binding of endogenous TRF1 resulted in telomere elongation. Components of the TRF1 complex are involved in functions in addition to telomere length regulation; for example, the TRF1 regulating protein TANK1 is required for sister chromatid separation at the telomeres during mitosis. The TRF2 complex plays a key role in the end protection function of

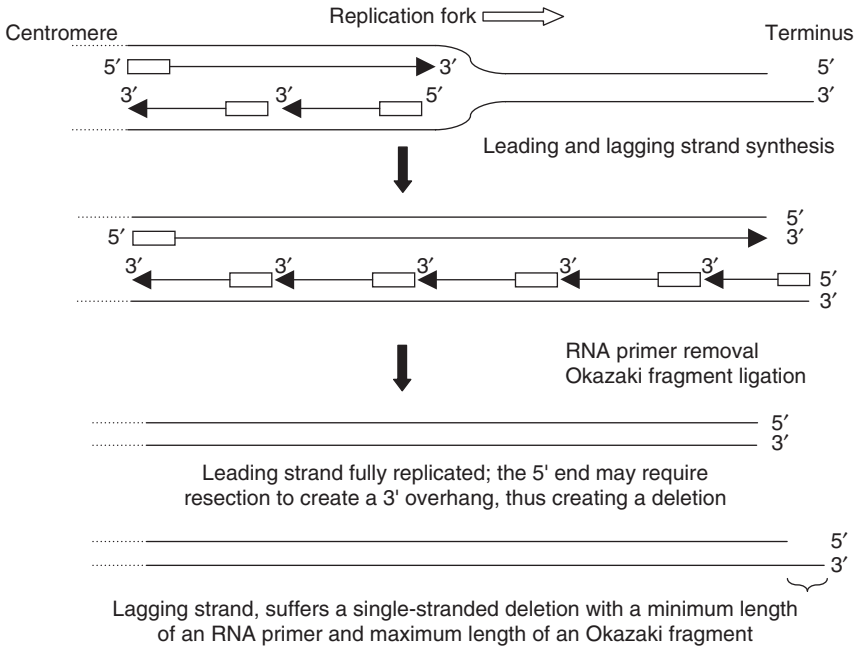

Figure 1 A schematic showing the end replication problem. When a DNA replication fork reaches the terminus of a linear DNA molecule, the leading strand (continuous) is fully synthesized. If the RNA primer (box) of the last Okazaki fragment of the lagging strand (discontinuous) is placed at the terminus, the strand will suffer a single-stranded deletion of the size of the RNA primer. Additional bases will be lost if the primer is not placed at the terminus. The 3′ overhang is required for telomere structure and function and as a substrate for telomerase-mediated lengthening. Thus, there may be a requirement for the leading strand to be resected to create a 3′ overhang; such an activity would result in an additional loss of telomeric sequences. When the daughter strands are subsequently replicated, the single-stranded deletion will be converted into a double-stranded deletion. In the absence of telomerase, the measured rates of telomere loss in human cells due to the end replication problem (plus the putative resecting activity) are between 50 and 120 bp/cell division.

telomeres; dominant negative TRF2 induces end-to-end telomeric fusions that are independent of telomere length. Interestingly, various proteins involved in DNA repair localize to telomeres via their interactions with TRF2 to form the TRF2 complex. Conversely, TRF2 and telomerase have been shown to localize to non-telomeric double-strand breaks. The details of the complex interplay between telomeric proteins and the DNA damage apparatus remain to be elucidated.

The Dynamics of Telomere Loss

The majority of human somatic cells display no detectable telomerase activity, the activity in humans being restricted to the stem cell compartments of actively proliferating tissues and at least 85% of malignancies. Both the human telomerase components have been cloned and characterized; the RNA component (hTERC) is expressed in all cell types, and the limiting component of telomerase activity is the expression of the catalytic component (hTERT). Recent reports have demonstrated that transient telomerase activity can be detected during S phase (in cells that were previously considered not to express hTERT). The function of this activity is currently unclear, but it could be capable of creating the terminal 3′ overhang that is important for end protection.

As Olonikov predicted, the expression pattern of telomerase means that in the majority of cell types, telomeres shorten every time the cells divide. This was first observed in 1990 by Harley and co-workers, whose analysis of telomere length in human fibroblast cells cultured *in vitro* revealed a gradual loss of telomeric sequences with ongoing cell division. Later, Allsopp and co-workers, in a study of cells obtained from donors aged between 0 and 93, observed a relatively weak correlation between replicative capacity and donor age, but, strikingly, a strong correlation was demonstrated between the proliferative capacities of cell cultures and the telomere length of the starting cell population. These observations made it clear that telomere length was a biomarker of cellular aging and led to the hypothesis that telomere erosion could account for the cell division counter that determined the Hayflick limit. Conclusive proof of this came after the cloning of hTERT and when it was ectopically expressed in mortal telomerase negative cell cultures (**Figure 2**). These cultures were shown to have stabilized the length of their telomeres and continued to proliferate well beyond their respective Hayflick limits.

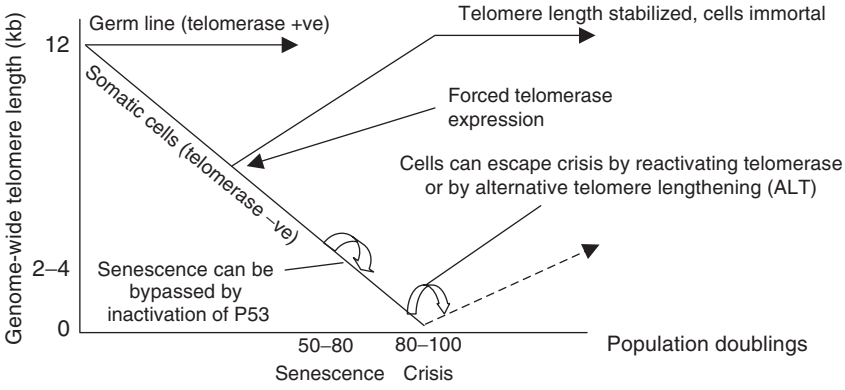

Figure 2 The relationship between telomere loss and replicative senescence. Telomerase expression in the germ line maintains telomere length for subsequent generations (germ line immortality). The majority of cells from somatic tissues do not express telomerase and therefore exhibit telomere erosion with ongoing cell division. Ultimately, the loss of telomeric function triggers a P53-dependent checkpoint known as replicative senescence. The forced expression of telomerase prior to senescence re-lengthens the telomeres and prevents the onset of replicative senescence; these cells are immortal. Replicative senescence can be bypassed by the abrogation of P53; for example, with HPV oncoproteins E6/E7, the cells continue to divide and lose telomeric sequences until a point termed crisis, which is characterized by extensive genomic instability and cell death. At a very low frequency in human cells, crisis can be overcome via the reactivation of telomerase or alternative telomere lengthening (ATL).

Importantly, however, other than their apparent immortality, these cell cultures did not demonstrate any of the characteristics of transformed cells; for example, they maintained their karyotypes, contact inhibition, and responses to serum deprivation. Replicative senescence is triggered when telomeres have eroded to a length at which telomeric functions can no longer be maintained. Neither the number of telomeres nor the critical telomere length at which senescence is triggered has yet been defined, but the minimum telomere length in senescent cells currently stands at around 1 kb. The loss of telomeric function triggers a double-strand DNA damage response triggering a p53-dependent G1/S cell cycle checkpoint. The abrogation of this checkpoint, for example, with the viral oncoproteins HPV E6/E7, leads to continued cell division and telomere erosion (**Figure 2**). This ultimately leads to a second proliferative life span barrier known as crisis that is characterized by genomic instability that probably arises as a result of extensive loss of telomeric function. In this situation there is a strong selective pressure for cells to stabilize their genome; thus, the cells that escape crisis have reactivated telomerase activity or found alternative routes to maintain telomere length.

The concept that the erosion of telomeres accounted for the Hayflick limit created an intense interest in the role that telomere biology may play in the human aging process. Telomere length is maintained in the germ line at its maximum length (10–20 kb) for subsequent generations by the expression of telomerase. However, in somatic tissues and cells, where telomerase is repressed in the majority of cells, telomere length is extremely heterogeneous, and this can confound the interpretation of telomere length data. This heterogeneity arises from multiple processes that influence cellular telomere length. The end replication problem is intrinsically heterogeneous (**Figure 1**), with each daughter cell receiving telomeric molecules of different lengths. Furthermore, the rate of loss observed in humans, typically 50–120 bp/population doubling, is less that that predicted by end replication losses alone and is less than observed in lower eukaryotes that have been engineered to not express telomerase. This suggests that human telomeres may be subjected to additional processing that causes more DNA to be lost from the terminus. Such activity has yet to be identified, but it could include C-strand resecting to create the 3′ overhang; clearly, such an activity would contribute to the overall heterogeneity of end replication losses. High-resolution telomere length analysis methods such as single telomere length analysis (STELA) are now available; these have revealed that in addition to the end replication losses, telomeres suffer sudden large-scale deletion events. Such events may be mechanistically similar to telomere rapid deletion observed in yeast and would contribute significantly to the overall heterogeneity of telomere length. In addition, there is some evidence to suggest that when compared to other genomic loci, telomeres may be more sensitive to oxidative damage. Indeed, telomeres were referred to by von Zglinicki in 2002 as sentinels for genomic damage. Oxidative damage contributes to rates of telomere erosion and telomere length heterogeneity in cultured human cells; the mechanisms are currently unclear, but they may include the induction of

telomere rapid deletion. The majority of our understanding of human telomere dynamics has been gained from cells grown in culture, and the kinetics of cell division of cultured cells can indirectly influence the measured rates of telomere loss. An extreme example of this is observed with Werner syndrome fibroblasts (a segmental progeroid syndrome) (*see* Premature Aging), these cells have an extremely attenuated replicative capacity. The majority of growth in the culture is accounted for by a small number of clones that are capable of growth; these eventually exhaust their replicative capacity and can be replaced by newly dividing clones. In this situation, the growth of the culture (measured as population doublings) does not equal the cell division of the proliferating clones. Thus, when telomere erosion is expressed as a function of population doublings it will appear to be elevated, when at a single cell level the rate is within the normal range. Thus, the kinetics of cell division both *in vitro* and *in vivo* will contribute to telomere length heterogeneity. In addition, as telomerase activity elongates the shortest telomeres in preference to the longest and adds heterogeneous amounts of telomere repeats, this will contribute significantly to telomeric heterogeneity, particularly in a tissue biopsy containing telomerase-expressing cells.

Implications for Human Aging

Despite the potential problems associated with the detection of significant correlations with such a heterogeneous system, information has been gained regarding telomere length and age in humans. Numerous cross-sectional surveys of telomere length in various human tissues have been undertaken. The key points from these studies are that telomere loss has been observed in human tissues, the extent of which varies between tissues and appears to correlate with levels of cellular turnover. For example, cerebral cortex and myocardium display negligible cell turnover and display no apparent telomere loss with age, whereas tissues such as the liver, kidney, lymphocytes, endothelium, and the epidermis all display varying degrees of telomere loss (**Table 1**). Furthermore, several datasets, particularly those obtained from peripheral blood cells, reveal that the majority of telomere erosion occurs during early life, appearing to stabilize during adulthood with further erosion in the later years. This could be explained by the increase in cellularity during early life; however, in tissues such as the immune system, skin, and gastrointestinal mucosa, whose function is supported by significant cellular turnover, telomere lengths may be stabilized by telomerase activity in stem cells. The

Table 1 Telomere dynamics and telomerase immortalization of human cells

Cell type	*Telomere loss*		*Telomerase activity*	*hTERT immortalization?*[a]
	In vivo (age)	*In vitro (population doublings [PD])*		
Bone marrow stromal cells	na	✓	Negative	Immortal
Chrondrocyte	✓	✓	Negative	Life span extension in low O_2
Corneal keratocytes	na	✓	Negative	Immortal
Endometrial stromal	na	✓	Negative	Immortal
Epithelial[b]	✓	✓	Negative	Immortal
Fibroblast[b]	✓	✓	Negative	Immortal
Hepatic stellate	na	✓	Negative	Immortal
Hematopoietic progenitor cells (CD34+)	na	na	Positive	No life span extension, enhanced survival
Hepatocytes	✓	✓	Negative	Immortal
Keratinocytes	✓	✓	Negative	Immortal only on feeder layers
Lymphocytes[b]	✓	✓	Transiently (following activation)	Life span extension
Myoblasts	✓ (in muscular dystrophies)	✓	Negative	Life span extension, not immortalized
Neural progenitor	na	✓	Negative	Immortal (>168 PD)
Osteoblasts	na	✓	Negative	Life span extension (>30 PD)
Retinal pigment epithelial	na	✓	Negative	Immortal
Retinal microvascular endothelial	na	✓	Negative	Life span extension (>100 PD)
Smooth muscle	na	✓	Negative	Life span extension (>100 PD)

[a] Several cell types require abrogation of p53 to facilitate hTERT immortalization; these were not included in this list.
[b] Similar results have been observed with the same cell types from several different tissues or in the case of lymphocytes in specific differentiated subsets.

majority of these cross-sectional telomere length studies were undertaken using terminal restriction fragment (TRF) analysis; this has several limitations, most notably its inability to detect the shortest telomeres that are likely to trigger replicative senescence. The correlations of telomere loss as a function of age are often weak and the telomere loss rates appear small. However, the problems with TRF analysis coupled with the inherent heterogeneity of telomeres may be masking more significant rates of erosion.

The hematopoietic system has been extensively studied for telomere dynamics and aging. It is becoming clear that, while the upregulation of telomerase activity in proliferating lymphocyte clones maintains telomere length in the early rounds of clonal expansion in response to specific antigens, this activity diminishes with repeated stimulation. Therefore, with successive clonal expansions, telomere erosion may limit the proliferative capacity of lymphocytes. Consequently, there is considerable interest in determining whether telomere-dependent replicative senescence may account for age-related immunosenescence.

More recently studies have been undertaken that utilize new developments in telomere length analysis and appropriate sampling to limit heterogeneity. These studies are revealing significant correlations of telomere length with age-related diseases and lifestyles. High-throughput quantitative PCR methods for telomere length determination have revealed correlations between short telomeres and psychological stress and that short telomeres in the blood increased the risk of mortality from heart disease 3.2-fold and from infection 8.5-fold in individuals over the age of 60; however, this risk was not significant in individuals over 75 years of age. Twin studies using TRF analysis revealed shorter telomeres in smokers and obese individuals. Telomere shortening in blood has been correlated with atherosclerosis, and quantitative trait linkage analysis using TRF data has revealed genomic loci that may contain telomere length regulators. While it is clear that telomere loss triggers replicative senescence and telomere loss occurs with age and can be modulated by lifestyle, a direct biological link between telomeres and human aging is tantalizing, but as yet not proven. However, the potential consequences of telomere loss in aging human tissues are becoming clear from both mouse models and human genetic diseases. Mice have long telomeres, and both cellular and organismal aging are not considered to be telomere driven in this organism. Consistent with this, telomerase knockout mice showed no phenotype in the first few generations. However, after four to six generations there had been sufficient cell turnover for the long mouse telomeres to have shortened sufficiently for the mice to exhibit specific phenotypes, some of which resembled age-related tissue deterioration and disease in humans. In addition to a reduction in longevity, these phenotypes included immunosenescence, with the mice showing a compromised reactivity of the germinal centers and a reduced replicative capacity of both T and B lymphocytes; age-related cutaneous phenotypes such as an impaired wound healing response and an earlier onset of skin ulcerations, hair graying, and alopecia; increased cancer incidence, which may have been a consequence of an increase in chromosomal fusions and aneuploidy; and weight loss due to a disruption of the villous architecture of the intestine. These phenotypes represent an extreme example of telomere loss and may not accurately model the gradual loss of telomeric sequences in long-lived organisms causing a progressive increase in the proportion of senescent cells over long periods. Nevertheless, they reveal the consequences of a loss of telomere function causing proliferative defects in tissues subjected to high levels of cellular turnover. Further insights into telomere biology and aging have come from human genetic disorders that result from mutations that affect telomerase activity. X-linked recessive dyskeratosis congenita (DKC) originates from mutations in the dyskerin gene (DKC1), a small nucleolar ribonucleoprotein (snoRNP) thought to be a pseudouridine synthase that may play a role in RNA processing. A second form of DKC results in the autosomal dominant form, which is a consequence of mutations in the RNA component of telomerase. The functional association of DKC1 with hTERC led to the realization that DKC is a telomerase deficiency disorder and that the DKC1 protein may be required for stability of the telomerase complex. Indeed, DKC individuals are haploinsufficient for the expression of hTERC, which results in lower levels of telomerase activity and shorter telomeres. Furthermore, like the telomerase knockout mice, DKC pedigrees display disease anticipation in which the age of onset and severity of the condition increases between generations, and this is associated with progressive telomere shortening from one generation to the next. DKC results in symptoms that show similarity to the phenotypes of the telomerase knockout mice; indeed, it has been described as a disease of premature aging. The defects primarily arise in proliferative tissues, the most profound of which are bone marrow failure or aplastic anemia, which is the most prevalent cause of death in DKC patients. The condition results in cancer predisposition and mucocutaneous features including leucoplakia of tongue, abnormal skin pigmentation, nail dystrophy, alopecia, and premature graying of hair. Thus, it is clear that telomere defects in humans

result in severe phenotypes, some of which resemble normal human aging. An understanding of the nature of the telomeric signal that triggers replicative senescence, for example, how many telomeres and how short they have to be, coupled with further work utilizing the new generation of high-resolution telomere length analysis technologies, will allow us to come to an understanding of the extent of telomere loss as a function of age in humans. In particular, documenting the accumulation of severely shortened telomeres that are capable of triggering replicative senescence will allow us to assess the functional significance in terms of age-related disease and tissue deterioration.

What about potential telomere-based therapeutics for age-related disease? As explained earlier, the key experiment that defined the role of telomere loss in triggering replicative senescence and accounting for the Hayflick limit was the bypassing of the senescence checkpoints by the forced expression of telomerase. By adjusting the culture conditions to minimize the impact of additional cell cycle checkpoints such as that mediated via p16, for example, by using physiological oxygen tensions and feeder layers, telomerase expression has resulted in an extension of replicative life span and often immortalization in numerous cell types (**Table 1**). These cells maintain their differentiated status and do not exhibit the characteristics of transformed cells. Importantly, these experiments have allowed us to understand that telomere-dependent senescence is widespread in human tissues. Furthermore, the understanding that many of these cell types exhibit age-related telomere loss *in vivo* led to the conclusion that telomere loss in these tissues is at least theoretically capable of triggering replicative senescence, and indeed that this can be prevented by telomeric stabilization via reactivation of telomerase. Some lines of evidence have emerged from animal models to support the concept that telomerase reactivation could have therapeutic potential. These include a mouse model in which *in vitro* aged dermal fibroblasts were incorporated into reconstituted human skin, which resulted in fragility and subepidermal blistering reminiscent of aged human skin, whereas the forced expression of hTERT in the same aged fibroblasts restored the phenotype. In addition, human bone marrow stromal cells ectopically expressing telomerase appeared immortal yet maintained their differentiated status and osteoblastic markers. Upon implantation into mice, these cells displayed an enhanced ability to produce bone compared to normal cells. In the telomerase knockout mice, experimentally induced liver cirrhosis was associated with telomere dysfunction; this was successfully treated by adenoviral delivery of the mouse telomerase RNA component to reconstitute telomerase activity.

The telomere barrier to unlimited replication imposed in most human somatic cells by a combination of telomerase inactivation and species-specific telomere lengths is considered to have evolved as a tumor suppressive mechanism. Thus, the reactivation of telomerase for therapeutic purposes would have to be carefully controlled, and the ideal therapy would use small molecule activators of the endogenous catalytic component of telomerase, the key advantages being that the reactivation of telomerase could be more carefully controlled, with perhaps a transient reactivation to re-lengthen telomeres and restore proliferative capacity. This work will be facilitated by a greater understanding of the genetics of control of the hTERT gene; currently it is known that estradiol can transactivate hTERT via the estrogen response elements in the *hTERT* promoter and that the oncogene c-Myc induces hTERT expression potentially via c-MYC binding sites (E boxes) in the hTERT promoter. Thus, the potential for small molecule activators of telomerase looks promising. In the absence of small molecule telomerase activators, alternative therapeutic strategies could be envisaged, the most promising of which could be the *ex vivo* manipulation of telomere length with hTERT expressing constructs, before being reintroduced into diseased tissue.

Telomeres and Cancer

Genetic instability is a hallmark of neoplastic transformation in humans; such instability is manifested by mutations at the DNA level or by gross chromosomal rearrangements. These rearrangements are required for epithelial carcinogenesis, occurring early in tumor development typically by the carcinoma *in situ* stage, after which the genome appears to stabilize with advancing malignancy. The apparent cessation of genomic instability appears to correlate with the activation of telomerase. Hence, there is considerable interest in the concept of telomerase inhibition as a potential chemotherapeutic agent for cancer. The later-generation telomerase knockout mice show telomere loss and genomic instability, which leads to both a lower age of onset and higher rates of tumor formation. Furthermore, mTERC$^{-/-}$ P53$^{+/-}$ compound heterozygous mice displayed a changed tumor spectrum from soft tissue sarcomas and lymphomas (observed in p53$^{+/-}$ mice) to carcinomas (observed in mTERC$^{-/-}$ p53$^{+/-}$ mice), demonstrating that an alteration in telomere length dynamics can cause a radical shift in tumor spectrum. Cytogenetic analysis

of tumors derived from late-generation telomerase knockout mice revealed high frequencies of chromosomes lacking telomeric signals, anaphase bridges, non-reciprocal translocations, and end-to-end fusions. These events were consistent with a loss of telomeric function resulting in genomic instability via cycles of bridge breakage and fusion driving early-stage neoplasia; this was in contrast to the analysis of tumors from early generation mice (with intact telomere function), which displayed no such events. Anaphase bridging can also result in complete chromosomal loss and the failure of cytokinesis, which can result in tetraploidization. These events, in particular non-reciprocal translocations, are observed in adult carcinomas but not pediatric cancer, in which reciprocal translocations are more common. Furthermore, an analysis of human pancreatic carcinomas revealed a negative correlation of terminal breakpoint frequency and telomere length. These data indicate a model whereby the loss of telomeric sequences with ongoing division during life in self-renewing tissues, most notably epithelium, results in telomere dysfunction. In the absence of a functional double-strand DNA break response, the ensuing genomic instability creates the appropriate rearrangements that may initiate tumor formation and facilitate the development to malignancy. The reactivation of telomerase re-establishes telomeric function and stabilizes the genome, allowing further tumor development. Thus, telomere loss as a function of age in self-renewing tissues may account for the age-related increase in carcinoma.

This model appears to contrast with the known expression profiles of telomerase in human somatic tissues, it being expressed only in the stem compartments of actively regenerating tissues. For example, proliferating keratinocytes at the basal layer of the skin epidermis exhibit high levels of telomerase activity, an activity that is absent in the more superficial layers. However, despite this activity a weak negative correlation of telomere length with age in DNA derived from skin has been documented. The mechanisms and cellular compartments that are responsible for this loss are currently unclear; however, it may be that the levels of telomerase are insufficient to fully counteract telomere loss or the additional mutational mechanisms other than end replication losses; for example, telomere rapid deletion may operate to create telomere loss even in the presence of telomerase. Thus, the stem cell compartments of highly proliferative tissues may be subjected to telomere loss, and the ensuing loss of genomic stability may underlie the age-related increase in cancer, particularly carcinoma.

Summary

The key role of telomere loss in the determination of proliferative life span of many human cell types has now been established. Telomere loss as a function of age has been documented in numerous human tissues and correlations observed with telomere length and age-related disease and stresses. Mouse models and human genetic diseases have clearly revealed the disorders of proliferative tissues associated with telomere shortening. *In vitro* studies have shown that it is possible to prevent telomere loss and the subsequent onset of replicative senescence, and rodent models have shown that it is possible to ameliorate some conditions with telomerase-expressing cells. This has opened up the real possibility of telomerase-based therapeutics for age-related and degenerative disease.

See also: Cancer and Age; Cellular Aging: Growth Factors and Cellular Senescence; Premature Aging.

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Theories of Aging: Biological

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Glossary

Aging – Any time-dependent change in an object or system. The change may be good, bad, or indifferent as judged by an observer.

Biomarkers (of Aging) – Hoped for but so far fictitious age-related changes that predict remaining life span. No age-related changes are predictors of life span in humans. Even in colonies of inbred animals under laboratory conditions efforts using physical, chemical, or biological measures have so far failed to predict individual life spans in any species.

Component Failure Death – Failure of a complex system of many nodes and connections and levels when some local or particular part or region ceases to have the dynamic range required for its contribution to the stability of the whole system. In medical and pathological terms, one says, for example, that the patient died of renal failure.

Degrees of Freedom (Dynamical) – The statistical meaning of this term is not relevant here. A system has one degree of freedom for every variable whose value must be specified to define the state of the system. It is the number of independent variables in a system. A simple physical example is the gas law $PV = nRT$. R and n are parameters (constant in any particular instance); P, V, and T are variables. Degrees of freedom equal the number of variables (here three) minus the number of laws of rules that bind the variables (here one) – thus two. When any pair of P, V, and T is specified, the remaining variable is no longer free, but is determined by the rule. In a complex system, when structures are added they act like rule constraints and reduce degrees of freedom. Paradoxically, the behavior of the system may be enriched. A gasoline spill burning in air has many degrees of freedom, but little behavior. When that burning is confined by the geometrical constraints of engine blocks and valves, torque can be applied to roadways through wheels and the possibilities enlarge. When structural genetic constraints bear on carbon chemistry degrees of freedom are drastically reduced, but system behavior enlarges.

Maximum Life Span Potential – A statistical extreme value for a population of members of the same species and birth cohort, under similar circumstances, that estimates the duration of life of the last to die. It is a random variable, not precisely determined by genotype or phenotype. (Caution: the statistics of extreme values is underdeveloped.)

Mortality Rate, $m(t)$ – As a function of age, $m(t)dt$ is the fraction of the surviving population that dies between t and $t + dt$.

Mortality Rate Doubling Time – In preference to the constant hazard term in the exponent of the Gompertz equation, which varies inversely with life span potential, the doubling time is a more natural unit for mortality rate acceleration because it is in the same direction as the life span and is measured in the same units of time. It is given by $ln2/C$, where C is the Gompertz exponent constant.

Negentropic Process – Any process occurring in a system not at equilibrium, which leads to a local increase in order (decrease in entropy), usually manifested as the appearance of a new structure. (The risk of confounding entropy and information is great, and is invited by the similarity between the Shannon formulation for selective information and Boltzmann's statistical entropy. That confusion will not be dealt with here.)

Process – Any time-dependent series of changes. The current condition may or may not depend on past conditions, depending on the type of process.

Senescence – Progressive loss of stability arising from the cumulative effects of by-products of otherwise normal, salubrious processes that increase the probability of system failure. It may be accelerated by interaction with or addition of other processes that are deleterious (e.g., smoking).

Specific Metabolism – Total energy conversion rate (a unit of power) per unit of mass of the active tissues and organs. In the case of mammals, for example, connective tissue, bone, and fat are often excluded, and the residue, a virtual lean body mass is used as reference total mass.

System Death – Failure of a complex system when all its parts, though compromised, are individually still within viable limits or specifications. A loss of connectivity is often involved.

Introduction

This article begins by setting a background for evaluating putative theories of aging. It contrasts physical and biological views of time, and regards senescence as a progressive loss with time of the competence of forms and functions. Senescence is the subject of interest. (The term 'aging' is neutral, encompassing any change, good, bad, or indifferent. However, in gerontology, aging and senescence are assumed for convenience to be synonyms, and so the simpler term 'aging' is used here also.) Next, facts, conjectures, hypotheses, and theories are contrasted, and some requirements for a comprehensive theory of aging are enumerated. It is shown by an example how biological 'facts' can be inflated into a (pseudo-) theory that addresses only an aspect of aging. Prior attempts to catalogue theories of aging have been inadequate, failing to neutralize George Sacher's strenuous complaint against mere 'aspect' theories. A selection of salient facts, that a synoptic theory of aging seemingly ought to accommodate and explain, follows. Finally, the article concludes with comments on several robust and general theories of aging.

Time: Biological versus Physical Time

Dynamic, biological time flows from a past through a present into a future, and is irreversible. It is anisotropic and has a direction. In contrast, physical time, as it appears in the great theories of Newtonian mechanics, relativity (special or general), or quantum field theory, is exactly or very nearly time invariant (i.e., time is isotropic, reversible). As the physicist David Mermin has remarked, in modern physical perspectives clocks do not measure some pre-existing thing called 'time' – the concept of time is just a convenient way to abstract the common behavior of things we call clocks. To the physicist, it is remarkably liberating to realize that time itself does not exist. The discovery that there is no time – only clocks – has deep and surprising consequences. There is no 'flowing' physical time.

Any attempt to reconcile biology and physics strategically will have to resolve this conflict about time. Until then our awareness that, barring accidents, illness, or catastrophic circumstances, we all grow old and die assures us that the metaphor of a unidirectional flowing time underlies any biological theory of aging.

Prior Attempts to Specify Theories of Aging

In 1990 Z. A. Medvedev made a heroic attempt at a rational classification of theories of aging. More than 300 so-called theories were grouped thematically, but the effort failed to escape Sacher's criticism that they were 'aspect' theories whose pluralism distracts from the development of a comprehensive, theoretical structure for gerontology. Aspect theories arise because specialized investigators with different disciplinary backgrounds perceive many diverse growing points for the development of theories about senescence. Unfortunately, there is a tendency for each aspect theory to become transformed from a fact or conjecture about an aspect of aging into a general, all-comprehending theory of senescence.

Example of the Invention of an Aspect Theory

First, select a set of experimental facts, such as the following:

- Fact: In eukaryotic cells the histone octamer, which comprises the protein core of the nucleosome (repetitive subunit of chromatin), forms a fiber that compacts DNA into a chromosome.
- Fact: Acetylations, methylations, and chaperones are involved in establishing and maintaining chromatin integrity and functions. (These structures and processes have been thought of as being part of an 'epigenome.')
- Fact: Core histones can be modified post-translationally by interacting through their protruding tails with many nuclear factors, thus acquiring the potential to serve as regulatory agents, especially

by modifications of highly conserved Lys, Arg, and Ser residues. (Conjecture: In this way histone modifications play a major role in the epigenetic integration of nuclear events. M. Esteller and colleagues advanced a histone code hypothesis based on these facts. The histone code hypothesis proposes that the combinatorial and/or sequential post-translational modifications of histone residues can be read by nuclear factors to promote different processes and determine specific states.)
- Fact: Identical twins, as they grow older, differ increasingly in their epigenomes. For example, chromosome 1 looks identical in monozygotic twins 1 year old. In such twins at age 50, there are striking differences between their chromosomes 1.

Now generalize the following: therefore aging is primarily a chromosomal, epigenetic phenomenon, brought about by non-genetic influences, systematic or random, such as growth factors, cytokines, stresses, pharmacological agents, and internal as well as external environmental fluctuations.

One sees in the preceding a mix of facts, conjectures, and hypotheses – all aggrandized into yet another aspect theory of aging. **Table 1** lists ten of the processes that sustain the life of multicellular organisms, each item inviting the invention of an aspect theory of aging.

Facts, Conjectures, Hypotheses, and Theories

- A biological fact is an observation or measurement, ultimately macroscopic (i.e., so a human being can recognize and interpret the datum), usually contaminated by 'noise' (any unwanted feature of the data, systematic or random) that may require removal by filtering. Facts are not theories, but as Darwin remarked in a letter to a friend, surely every fact is for or against some theory.

Table 1 Ten requirements to sustain the life of a eukaryotic, metazoan organism[a]

1. Maintain differentiated specialization of genes
2. Assure faithful replication of DNA
3. Preserve chromosomal integrity (but allow for telomeric shortening with normal cell divisions)
4. Remove, sequester, or repair defective proteins
5. Quench free radicals not required for essential reactions
6. Detoxify noxious agents
7. Defend 'self' against alien materials
8. Protect against environmental shocks
9. Heal or replace worn or missing parts
10. Defend *milieu interieur* by means of regulations and controls

[a] There is at least one aspect theory of aging addressing each of these desiderata. (Of course, to sustain a species, replication or reproduction must be added.)

- A conjecture is a conclusion or supposition deduced by surmise or guesswork, or inferred from defective or presumptive evidence.
- A hypothesis is a tentative assumption or model made in order to draw out or test its logical or empirical consequences.
- A theory is a plausible, scientifically acceptable general principle or set of principles offered to explain phenomena such as a set of facts in their relation to one another. (In a formal theory, the general principle is expressed mathematically.)

P. Suppes has illuminated the procedures for theorizing in mature physical sciences. To develop a model on theory, an idea is expressed in text as generally as seems appropriate. If possible, the text is then formalized as a mathematical model, still very general. The model is then specified for a particular application by ancillary constraints. This constrained model on theory is then compared to an empirical model of data, generated by observations and measurements, filtered to remove noise, and then treated statistically by curve-fitting or other procedures. The two models are compared and tested for logical isomorphisms. Unfortunately, the greatest theory of the life sciences – some version of Darwinian evolution – does not fit comfortably into this scheme, emphasizing as it does chronicles rather than dynamics.

A Random Selection of Salient Facts That a Satisfying Theory of Aging Might Accommodate

A valid fundamental theory of aging is not required to explain all available facts in all members of one species and among all species. George Martin usefully emphasized that in light of evolutionary theories, a fundamental process of aging need not create a universality of phenotypes. Some mechanisms may indeed be 'public,' but others can be 'private' (i.e., "they may reflect patterns of decline in structure and function that are idiosyncratic…").

A typical life span (as framed genetically for each mortal species) may be thought of as consisting of three epochs: (1) development to onset of reproductive capability, (2) maturity, constituting a 'health span' during which the organism can explore its behavioral repertoire without limitation, and (3) a senescent decline to death. The length of the life span is not as important as the health span. Does evolution optimize anything other than reproduction? Is there a 'drift toward smarts'? This is a contentious issue. What do we want from a fundamental theory of aging? What are the facts that most need an

explanation from such a theory? The following list presents 16 candidates. Facts that are contended are marked with an asterisk.

1. Among all the species of living organisms (the number of species being variously estimated to be from 10 million to 30 million, with only a small fraction identified so far), there are some species whose individual organisms will always die, even if they escape accidents or predation or catastrophic environmental change, i.e., members of such species are mortal. In contrast, some coelenterates and all prokaryotes do not express any life span limitation. Some trees have vegetative reproduction and do not age.

There are some ambiguities to this fact, however: (1) Many living forms have complicated life cycles (e.g., insects that go through the stages of egg, larva, pupa, imago, and egg again) that confound attempts to define the organism. Each stage is limited in time, but the cycle may endure indefinitely. (2) The slime mold *Dictyostelium discoideum* has a stage of free-swimming, single-celled amoebae that can aggregate to become one multicellular organism with differentiated parts. (3) The Portuguese man-of-war presents as a single organism but is actually a colony of four different types of polyps, one of which serves reproductive functions by sexual and asexual methods, leading to free-swimming larvae that can generate a new colony with differentiated parts.

2. For species whose members are mortal, population data can generate survival curves for a cohort. The shapes of these curves should be rationalized by a theory of aging. These curves are non-linear, and they have two strong parameters, the median life span and mortality rate doubling time (MRDT), and one weaker parameter, the maximum life span. The maximum life span is by definition an extremum, and there is no agreed-upon statistical approach for it. Jeanne Calment, for example, lived 122 years, 5 months, and 14 days; her life currently sets the documented extremum for human maximum life span. (But someday a person with a documented birth date may be found to have lived longer.)

3. The median life span for successive cohorts of a species can undergo substantial changes over time periods much too short for there to have been a genetic basis for the changes. For example, the median life span for human cohorts born in the United States increased more than 30 years during the twentieth century, largely because of improvements in medicine and public health, leading to decreased infant mortality.

4. *Normal eukaryotic cells with mitotic potential do not continue to divide indefinitely when cultured under special, idealized laboratory conditions (unless they become transformed into cancer cells). However, there are a few studies in which the phenomenon of clonal senescence has not been observed.

5. In all mortal species tested so far, some degree of caloric restriction (usually a reduction by about 30 to 40% of the *ad libitum* intake under the laboratory conditions) will lead to an appreciable increase in median (sometimes also maximum) life spans of a sheltered population.

6. Certain single-gene (point) mutations in some organisms favored for genetic research in this field (e.g., daf-2 or age-1 in the worm *Caenorhabditis elegans*, RAS_1 in budding yeast *Saccharomyces cerevisiae*) can lead to increased life spans (but usually with reduced fertility) under laboratory conditions.

7. The non-linearity of human population survival curves can be approximated by the famous Makeham-Gompertz model for mortality rates:

$$\mathrm{m}(t) = A + B\ \exp C(x - 30)\ (30 \leqslant x \leqslant 80), \quad [1]$$

where $\mathrm{m}(t)$ is observed mortality rate, A is an age-independent but environmentally dependent mortality rate, B is an intrinsic, initial, age-independent but slightly environmentally dependent mortality rate, and C is the Gompertz hazard parameter. It can be interpreted as an 'aging rate' expressed as a mortality rate doubling time (MRDT). MRDT has a value of about 8 years for humans, 3 months for mice, and 10 days for fruit flies. It is age independent over the human age range from 30 to 80 years, after which MRDT may (counter-intuitively) spontaneously increase. It is almost environmentally independent, except that under special conditions of partial caloric intake restriction in our laboratory, MRDT can be increased so that lifespan is prolonged.

8. *In spite of the Gompertz non-linearity for mortality of populations, cross-sectional data from healthy human beings living in developed countries manifest a kinetics of senescence (rates of the progressive losses of individual forms and functions) that are roughly quasilinear between ages 30 and 70 years, with a median slope of –0.5% per year loss rate from the initial condition (100% reference) at age 30 years:

$$y_x = -r(x - x_\mathrm{o}) + 1\ (30 \leqslant x \leqslant 70), \quad [2]$$

where $x_\mathrm{o} = 30$ years, $x =$ chronological age rounded to nearest year ($30 \leqslant x \leqslant 70$), y_x is the fraction of capacity at age 30 that is left at age x (capacity at age 30 is 1.0), and r is the fractional change per year (a loss rate via the negative sign; $r \approx 0.005$).

Whether or not these kinetics extracted from cross-sectional data are indicative of what happens

to the population of parts and processes within an individual remains to be seen. A formal model has been developed that shows that for population data there is no contradiction between a set of averaged linear loss rates and an exponential hazard function, provided that there is a dispersion or variance associated with the set of linear losses.

9. Under laboratory conditions, repetitively selecting for survival and maturation eggs only from the oldest fruit flies ultimately leads to generations of longer-lived flies. This result was anticipated by the assumption that because of antagonistic pleiotropy, a strong artificial selection rewarding females capable of late reproduction should select against those pleiotropic traits that are most antagonistic to long-term survival.

10. Transplantation of a nucleus from a mature, adult, differentiated mammalian cell into an enucleated mammalian ovum (e.g., cloning) can, under special circumstances (so far with low probability), support the complete set of processes of implantation, embryogenesis, fetal growth, birth, and development of a new young animal. The life span potential of such creatures is still uncertain. Dolly, the first mammal cloned by nuclear transfer of a cell from an adult (6 years old) was born on July 5, 1996. Her expected life span, were she actually a young newborn lamb, was 11 or 12 years. However, she soon became arthritic and suffered progressive lung disease – afflictions typical of very old sheep. Mercifully, her caretakers put her down before she was 7 years old.

11. *Hybridizations of young and old cells indicate that the senescent condition dominates the result.

12. The median life spans for populations of different species in the same taxonomic class (e.g., class Mammalia) cover a wide range (several orders of magnitude for mammals, whose body weight range for the placental terrestrials covers six orders of magnitude from shrews to elephants). Linearized, allometric (log-log) scaling plots for the model $y = a(x)^b$ of selected morphological or physiological features (y) vs. body weight (x), where y includes life span, heart rate, surface area, and metabolic rate, typically have positive slopes (b) of 0.20 (life span) to 0.75 (metabolic rate). The exact values are in dispute, and some entries lie far off the general line. Nevertheless, there is a strong tendency for the life span of different mammalian species to increase with size across species. Within a species this trend need not hold – large dogs, for example, do not live as long as small dogs.

S. Austad refined the size-longevity relation by defining a new term, longevity quotient (LQ), obtained for a species by measuring the departure in longevity from the value expected for a specific body size according to allometric scaling rules. An LQ of 2 means that an animal lives twice as long as expected from size alone. The LQs are not immutable: opossums living in an environment without predators have evolved a pattern of reduced litter size, longer lives, and slowed aging rate compared to opossums living in areas where predation is a major risk.

Among the mammals (some kept in zoos) that Austad considered, giraffes, African lions, and African elephants had LQs of about 1.0. The LQs of white-eared possum, Asian house shrew, and Asiatic wild dog were low, about 0.4, and those for various bats (African collared fruit bat, vampire bat, greater horseshoe bat, little brown bat) were all high, 3.1 to 5.8. (The little brown bat is smaller than a mouse, but even in the wild it lives ten times as long as does a mouse in a protected laboratory environment.) Humans come in at 4.2. That means that according to conventional allometric scaling, given our size we should live only about 25 years. A comprehensive theory of aging should account for the general allometric scaling approximation and for the departures from it.

13. Older organisms lose homeodynamic competence, including the ability to resist stresses and produce heat shock proteins.

14. *All the cells in adult *C. elegans* are postmitotic except the gametes. If a mutant delays maturation, the life span of the worm will be increased, but the span after maturity is reached is not changed.

15. Canaries and mice are about the same size. However, canaries have higher body temperatures, faster heat rates, and blood glucose levels twice as high – so high that such levels in mammals would lead irreversibly (via the Maillard reaction) to advanced glycosylated end products (AGEs) and separately to sorbitol – substances not cleared from cells. Yet in protected environments, canaries live ten times as long as mice.

16. Women live longer than men in all cultures (except those in which girls and women are treated badly compared to males). Human females are definitely the hardier sex biologically, yet their aging rate (mortality rate doubling time) is the same as that for males. They simply die at a lower rate at all ages. Longevity itself is not a marker for any supposed universal, fundamental aging process.

This list is just a sampler; there are many other plausible facts eligible for attention by a comprehensive theory of aging. However, those shown here are indicative of their variety.

Major Classes of Current Theories of Aging

Because of the prevalence of age-associated diseases it might be supposed that senescence itself is a disease (for which a cure might be found). But because (by definition) mortal organisms that have avoided diseases, accidents, or predation and survived any overwhelming environmental changes and challenges all grow old and die, it is plausible to adopt a first assumption that there is an underlying cause (to be discovered) that inevitably leads to senescence, frailty, vulnerability, and death – whatever the circumstances. The manifestation of this process is the mortality rate doubling time, not longevity itself.

Exactly when senescence begins during a life span is not known. However, for human beings a second assumption is that up to (about) 30 years, growth and development dominate the life trajectories, and the fundamental process causing senescence begins right after their completion, exerting effects even during the health span of mature middle life and continuing to the end. (But see the reliability theory discussion of initial and early defects that set up later aging events.)

Table 2 lists a sample of theories that have been widely and seriously considered. Some have been proven false and were rejected or reinterpreted. Two durable ideas remain as dominant classes of comprehensive theories of senescence: (1) evolutionary theories and (2) free radical theories, originating in 1956 and 1952, respectively.

Ernst Mayr has insisted that biology is unique among the sciences, and should not and cannot be 'physicalized.' If so, then there is little to be gained from applying the strict requirements of theory building in physics to developing biological theories of aging. Indeed, given the stupendous diversity of living creatures (none being exactly alike, whereas all electrons are alike), it may be that no overarching theory of aging can ever be achieved. However, the search may not be hopeless – recall the comments of George Martin cited earlier. Perhaps there are many different ways that mortal organisms living under favorable conditions, and with good luck, grow old and die even under the agency of some universal aging process. The biosphere is supremely rich in possibilities.

It would be a high price to pay if gerontologists abandoned the demanding (Popperian) requirement for validating hypotheses and theories in the physical sciences; deductions or inferences from them, under constraints, must lead to specific protocols for empirical tests that could (at least in principle) falsify them. Were we to abandon that criterion for validity, theorizing in gerontology would consist merely of collecting Kiplingesque 'just so' stories. (Ironically, it is not yet clear that the string, M, and loop quantum gravity theories at the forefront of theorizing in physics today can ever be tested empirically.)

Evolutionary Theories of Aging: Some Highlights

When one invokes natural selection as a causal basis for phenomena in biology, as the evolutionary

Table 2 Theories of aging[a]

- **Error catastrophe** (Leslie Orgel – who later withdrew the claim when it was disproved. However, reinterpretations based on new data justify reconsideration.)
- **For-the-good-of-the-species theory** (once rejected, but now being reconsidered)
- **Evolutionary theories of aging (Peter Medawar)**
  - Disposable soma theory (Tom Kirkwood)
  - Antagonistic pleiotropy (George Williams, Michael Rose)
  - Late-acting genes (J. B. S. Haldane)
  - Longevity versus early reproduction trade-off (Maynard Smith, Steven Austad)

    Though their reasons differ somewhat, these views all hold that natural selection will be ineffective in purging genes that exert deleterious effects only late in life, after reproduction has already occurred (artificial selection for late reproduction can delay their effects). Senescence and mortality are caused by the expressions of such genes, many of which are 'normal,' in that they serve early to support life during growth, development, and reproductive maturation.

Wear-and-tear theories
  - Thermodynamic (Eugene Yates)
  - Free radical (Denham Harman)
  - Rate-of-living, also known as metabolic rate theory (Max Rubner; Raymond Pearl) (disproved)
- **Limited cell division theories** (telomere shortening, replicative senescence) (Now rejected as an essence of aging, but still regarded as an important, normal biological phenomenon.) (Leonard Hayflick)
- **Reliability theory** (Leonid Gavrilov and Natalia Gavrilova)

[a] This table contains a selection of some of the major themes that have been frequently invoked as theories of aging. When the origin of a proto-theory is associated with particular scientists, those names are given. Some of the theories are stochastic in nature, and others are programmatic/deterministic. (The listing is not in chronological order.)

theories all do, especially with regard to reproductive behaviors, the assignment of energy budgets, and longevity, one risks making anthropomorphic projections onto the data and seeing adaptations where there may be only by-products of other causes not comprehended.

Evolutionary theories apply only to reproducing systems exposed to a natural selection characterized as a 'force' that diminishes with age. For example, assume a dominant, dangerous gene effective in single copy, with delayed expression, that reveals its lethal mischief only after the host carrying it has already matured and had offspring. Such a deleterious gene will be propagated and cannot be eliminated from a population by natural selection. An example is the gene for Huntington's disease in humans. Generalizing, there may be other genes, persistent in a population, whose late expression will limit life spans.

Because the force of natural selection diminishes with age, the force of mortality, i.e., probability of dying, increases with age. A variation on the above scheme would be the assumption that there are normal genes (to be identified) that act beneficially during growth and development, but act detrimentally later under the changed context provided by differentiation and maturity, at which time they cause senescence, i.e., they exhibit antagonistic pleiotropy. (A single pleiotropic gene has multiple effects involving multiple changes in expression of other genes. In aging research, loosely, a gene is pleiotropic if it produces different effects at different stages of a life span as physiological contexts change.) The continued expression of such genes eventually weakens the organism. They cannot be eliminated by natural selection because normal offspring would have already been produced. Actions of many such genes could be common, non-threatening, and 'invisible' in short-lived species, but produce morbid 'gerontogene' effects in long-lived species.

If there are gerontogenes, they need to be better characterized. Which ones are they? (Genes for insulin-like growth factor receptor type 1 [IGF-1R] are considered to be a putative 'public' candidate operating in many species. If their expression is decreased, life span may increase.) How big is the set? How widely distributed are they? What do they do or fail to do, alone or in concert?

It is often stated that the costs in resources and energy of reproduction may diminish the means available to meet the maintenance requirements listed in **Table 1**, but there is no physical law or biological rule that says this has to be so. Nevertheless, from an evolutionary point of view, the need for high quality of cells in the germline surely outranks that for a 'perfect' soma, and quality is usually expensive. Some experiments indicate that delaying the onset of reproductive capability will extend life span. But, as noted previously, the actual aging rate of *C. elegans* so treated is unaltered once maturity is reached after the delay.

Another plausible evolutionary argument (the disposable soma theory) supposes that organisms, especially small ones, living in dangerous environments should mature rapidly and get on with reproduction, and not invest heavily in long-term maintenance processes, as this would seem to make evolutionary sense. But examining the time budgets for energy expenditures of such creatures (e.g., mammals) reveals that they mainly (1) eat to move, (2) move to eat, (3) repair and maintain form and housekeeping functions, (4) sleep to refresh, and (5) play. They spend little time in reproduction (although when they are in the reproductive mode, as when a female mammal is in heat or estrus, and males are responding or carrying out courtship rituals, including fighting, there is a concentration of energy expenditures on those processes, and there may be frenzied motor activity and no eating until they are over).

To support this version of the evolutionary story, it would help to demonstrate that the total lifetime energy budget of small, ground-based, short-lived mammals (for example) assigns a much greater portion to reproductive behavior and pregnancies than on the other processes listed previously, compared to bats (for example) of the same size who suffer less from predation and live longer. Until that is done, this evolutionary story remains seductive but not absolutely compelling. However, Tom Kirkwood, the inventor and champion of the disposable soma theory, which insists on the evolutionary benefits of a trade-off in the use of resources that favors reproduction over maintenance (within limits), stoutly rejects the criticism that resources are typically sufficiently abundant so there need be no such trade-off.

Regardless of the merits of the evolutionary argument from partitioning of resources, from a game-theoretic perspective it is indeed the case that in dangerous environments small animals that mature and reproduce early will necessarily change gene frequencies in favor of those very characteristics as time goes by, whether or not they underinvest in maintenance. Slow developers and less fecund animals in competition are naturally eliminated eventually.

Books have been devoted to various evolutionary theories of aging, and the preceding short selection of highlights can not do them justice. Some version of evolutionary theorizing is currently very popular among gerontologists and strongly advocated by many experts who believe that it is the theory of

aging. But demographic studies of normal strains of fruit flies show that the well-documented slowing of the mortality rate at advanced ages seems to start at the end of reproduction. If late-occurring expression and deleterious effects of genes that normally favor reproduction over sustained maintenance cause senescence, then the rate of aging might be expected to continue to increase at advanced ages, contrary to fact. (There is necessarily a survivor bias in data from old organisms that confounds predictions for heterogeneous populations, but the slowing is also seen in the more homogeneous highly inbred strains.)

Wear-and-Tear Theories

There is intuitive appeal to the idea that mortal living things eventually simply wear out, as do automobiles, following requirements of the second law of thermodynamics. A problem with this notion is that, in contrast to automobiles, living things are self-organizing and self-repairing, without requiring the services of a *deus ex machina*. Therefore, there is no obvious reason that they should inevitably become senescent and die, if they avoid accidents, sustained stresses, and changes in their environment that challenge them beyond their capacity to adjust and adapt.

Wear-and-tear theories invoke entropic consequences to organisms of the normal dynamics of their daily rounds. At maturity their processes that use or transform the Gibbs free energy required for maintenance and for operations (movements, syntheses, material turnover, charging cell membranes, propagating nerve impulses, etc.) necessarily occur away from, and do not lead to, equilibria. (No useful work can be accomplished at an equilibrium.) Instead, near-steady states appear.

In the last half of the twentieth century, Ilya Prigogine developed non-equilibrium thermodynamics and illuminated its potential for explaining creative chemistries that support the sudden appearance of structures in previously homogeneous media. He and many others extended the concepts mathematically, using bifurcation theories, fractals, criticality conditions, phase change theories, chaos, non-linearities, irreversibility, and dissipative processes, to establish a modern non-linear mechanics sufficiently rich to attack the mysteries associated with all self-organizing systems. Recently, E. Schneider and D. Sagan have dramatically shown how creative the second law can be in open systems.

F. E. Yates and L.A. Benton have applied some of these themes to the problem of explaining senescence. It is necessary to go beyond classical thermodynamics, which is a completed science that best deals with equilibrium states and quasi-static, linear trends toward equilibrium, from initial conditions not at equilibrium, in isolated systems that cannot exchange energy or matter (or information) with an environment. (Equilibrium is a state that applies separately to individual processes, but not to systems globally. Thus, there are separate mechanical, electrical, chemical, thermal, etc., equilibria to be considered in systems analyses.) The familiar, established features of natural processes in isolated systems, according to classical thermodynamics (i.e.., as they move toward an equilibrium state specified by the constrained conditions, Gibbs free energy decreases and entropy increases) do not suffice to explain or predict the rich behavioral potentials of open systems. Open systems, by definition, interact with environments and can obtain or replenish free energy supplies as well as eliminate products of molar entropy higher than that of those taken in. E. Schrödinger noted that, in this way, thermodynamically open, living systems can be said to feed on 'negentropy,' thus maintaining their internal order and preventing degradation. But Schrödinger's attractive notion fails to set up an explanation of senescence. Unfortunately, because the thermodynamics of open systems is a science still under development, any attempt to remedy its deficiencies may require new conjectures or hypotheses.

Senescence from the Perspective of Thermodynamics of Open Systems

An explanation for senescence, based on a view of open-system thermodynamics, might well begin with the observation that metabolism operates through many cyclic processes. Each metabolic cycle, as a natural process, necessarily (second law) generates an internal gain in entropy (ΔS_i) with destructive potential. The fundamental question for gerontology then becomes the following: can exchanges of matter and energy across the boundary of an organism compensate fully for the positive ΔS_i leaving no net entropic gain internally? That is, can the following two statements both be true?

$$\Delta S_{i\ (\text{metabolism})} - \Delta \hat{S}_{i\ (\text{compensation})} = 0$$
$$(\text{i.e., maintenance is perfect})$$

where $-\Delta \hat{S}_{(\text{compensation})}$ is a negentropic effect, and

$$\Delta S_{i\ (\text{metabolism})} - \Delta \hat{S}_{i\ (\text{compensation})} + \Delta S_{(\text{environment})} = \Delta S_{\Sigma} > 0 (\text{i.e., second law satisfied}).$$

With respect to an open system such as an organism, with many active transport systems at its boundary, it might be supposed that during or after each metabolic cycle, the following could be true: negentropic $\Delta\hat{S}_{(\text{compensation})} \geqslant$ positive $\Delta S_{(\text{metabolism})}$ internally. If so, it would permit perfect maintenance and defy senescence. However, there is a difficulty, because whatever constitutes negentropic $\Delta\hat{S}_{(\text{compensation})}$ internally has to be the result of a natural process itself, and therefore also a generator of some positive ΔS_i, even as it supplies a (lesser) negentropic benefit to some local internal region. Therefore, it is postulated that metabolic processes in open systems always tend toward a net accumulation of entropy internally, especially in cells that cannot divide. That accumulation universally drives senescence. During cell divisions, such as those that occur during growth and development, the internal states perhaps can be reset or renormalized so daughter cells do not necessarily inherit all the entropic accumulations of the parent cell. But after differentiations there are many tissues and organs with postmitotic cells, and those conspicuously do senesce.

Consequences of Freezing Out Degrees of Freedom during Development

Another physical reason for the inevitability of senescence has to do with a universal property of self-organizing systems: they are self-scaling in time, space, and energy. For example, a human being at maturity is scaled to operate with a daily energy budget of about 2000–3000 kcal/day. (Transiently, this budget can be increased to more than 6000 kcal/day, as in Tour de France cyclists, but at a cost of material breakdowns that will end the effort.) During growth and development, stages with many negentropic features, by definition, the specific-energy budget (energy per unit mass) is substantially increased by the costs of construction, including differentiations. Construction requires that dynamic degrees of freedom be available for creation of new parts. While that condition is met, the net effect of energetic transactions can be negentropic internally. At maturity, those degrees of freedom have been frozen out by the structures made, which provide new constraints on dynamics. As a result, all further energy transformations must then follow the preceding scenario, in which a net accumulation of destructive internal entropy is inevitable, manifested as eroded constraints and weakened couplings and connections. This is a central, general thermodynamic cause of senescence in mortal metazoans. Starting as soon as maturity is reached, the net internal entropic accumulation begins to displace a living system from its normal optimal operating point. Details will vary within and across species, but controls and regulations will always breakdown.

Prominent agents of the destructive effects of the internal entropy increases arising as by-products of metabolism are free radicals.

Free Radical Theory of Aging

The free radical theory of aging proposes that free radical oxidants produced during aerobic respiration play a major role in the disintegrations of aging. Especially potent are products associated with energy consumption by mitochondria that generates the leading oxidants $O_2^{-\bullet}$ (which can also be a reductant), H_2O_2, and $^{\bullet}OH$ (the most destructive to biomolecules). For convenience they are often referred to together as reactive oxygen species (ROS). ROS, as noted previously, are postulated to be particular agents of the entopic residues of metabolism (ΔS_i) required by the general thermodynamic theory.

A substantial literature is now available addressing three important questions, among others: (1) Do ROS play a role in degenerative senescence? (2) Do they determine mortality rates of different species? (3) Are mitochondria particularly vulnerable to age-associated pathology?

The discovery that respiring cells have numerous agents that can quench free radical metabolic 'sparks' and afford damage control lends credence to this theory. Beckman and Ames have assembled an impressive database that identifies these agents and supports the general claims of the theory. For example, transgenic fruit flies with enhanced antioxidant defenses show extended mean and maximum life spans, and large deletions of mitochondrial DNA have been found in older organisms of many species. Yet mysteries remain. Why does oxidative dysregulation take so much longer in humans than in mice? And why does caloric restriction so powerfully extend life spans when it has little or no effect on specific metabolic rates? However, even considering these questions, the free radical theory of aging is doing very well.

Reliability Theory

All the theories discussed previously have existed for many years. Reliability theory, however, is an original, new theory that, among its many virtues, can even be formalized. The need for a new theory is illustrated by the circular reasoning that explains aging at the level of the organism by aging changes at

the molecular and cellular levels, leaving aging still a mystery. (Stable isotopes of atoms do not age.) But, at higher levels of organization, components may fail at random, with a constant risk of failure independent of age. Furthermore, complex systems in general can have failure modes peculiar to their global organization – this is system failure, as opposed to component failure.

Gavrilov and Gavrilova argued that gerontology needs a general theory of systems failure, known as reliability theory. This class of theories was developed to describe failure rates observed in electronic equipment, but it has a very general applicability. Reliability is described by the function $S(x)$, which is the probability that a system or component will continue to operate properly according to a standard of merit:

$$S(x) = P(X > x) + 1 - P(X \leqslant x) = 1 - F(x),$$

where x is time, X is time to failure, P is the probability that failure time X is beyond time x, and $F(x)$ is a standard cumulative distribution function in probability theory.

From that starting point, Gavrilov and Gavrilova brilliantly developed their theory and proved that the phenomena of the mortality increase with age and subsequent leveling-off are theoretically predicted to be inevitable features of all reliability models that consider aging as a progressive accumulation of random damage. They next demonstrated the importance of redundancies and parallel structure in protecting complex systems by establishing damage tolerance. However, as time goes by, the redundancy in the number of elements decreases, so fragility increases. Finally, they formally introduced the hypothesis of high initial damage load. As modeled, this hypothesis predicts that even a small advance in optimizing early developmental processes can potentially prevent the occurrence of many diseases later in life. Furthermore, it has the capacity to postpone aging-related morbidity and mortality. These features of their theory are especially welcome now that the epoch of intense genetic reductionism in biology has been replaced by the more mature understanding that between the genome and the global phenotype lie many aleatory, epigenetic, developmental events.

The reliability theory of Gavrilov and Gavrilova has the power to address an astonishing range of phenomena of interest to gerontologists, and substantial data sets are offered in its defense. It has no rival for its predictive and explanatory power. It is not possible to show its rich details here, but the references cited provide the substance and beauty of the theory.

See also: Homeostasis, Homeodynamics and Aging; Markers of Aging; Models of Aging: Vertebrates; Theories of Aging: Psychology.

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Theories of Aging: Psychology

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Glossary

Chaos Theory – States that fluctuations of far-from-equilibrium systems can create order out of chaos through a process of self-organization.

Gerodynamics – Dynamic systems theory of aging, based on general systems theory and chaos theory.

Gerotranscendence – Shift in meta-perspective from a materialistic and rational vision to a more cosmic and transcendent one.

Gompertz' Law – States that there is regular acceleration in the rate of death with age from about age 10 to the end of the usual life span.

Psychology of Age – Study of age differences in behavior.

Psychology of Aging – Study of behavioral patterns of change with age.

Psychology of the Aged – Study of problematic and non-problematic behavior in the elderly.

Introduction

Research in the psychology of aging has been guided by a diverse collection of theories. Historically, there are three approaches: the aged, age, and aging. The psychology of the aged focuses on the behavior of older people. Grounded in a stages-of-life perspective, most studies of the aged demonstrate a thematic approach and little coherence, e.g., studies of Alzheimer's disease, retirement, widowhood, etc. The psychology of age studies age differences in behavior by comparing groups of people of different ages in cross-sectional research. Productive research focuses on identifying the causes and consequences of the processes responsible for age-related differences, e.g., processing speed, attentional capacity. The psychology of aging studies behavioral patterns of change with age, integrating both the psychology of age and the aged in longitudinal research. In this article, major but diverse psychological theories of aging are presented chronologically, beginning with early nineteenth century theorizing on processes of aging.

History

Early Roots

The roots of psychological theories of aging lie in the European soil of nineteenth century science. The intellectual climate fostered a strong conviction that the scientific method could be applied to all natural phenomena and that all matters could be examined by research and reduced to lawful generalizations, including the subject matter of aging. In 1825, the English actuary Benjamin Gompertz published his classic paper on the force of mortality, which expresses a lawful relationship between death rates and age within a given population. He noted the regular acceleration in the rate of death with age from about age 10 to the end of the usual life span. The regularity of this observation has led to much research into the genetic and biological basis of aging and the causes of death.

While scientific effort was devoted to identifying specific relationships such as Gompertz' law, the Belgian mathematician and astronomer Quetelet attempted to demonstrate that all facets of the changes in human behavior across the life span were lawful. In 1835, he published his book on man and the development of his faculties. In addition to information about differences in mortality rates, he included material about physical and behavioral characteristics of people according to age. As a mathematician, Quetelet emphasized observations of many individuals that would lead to the characterization of the average man around whom observations are distributed. His commitment to studying the lawfulness of the life span is seen in the following statement: "It will first be necessary to determine the period at which memory, imagination, and judgment commence, and the stages through which they necessarily pass in their progress to maturity: thus having established the maximum point, we may extend our inquiries to the law of their decline." Quetelet's thinking represented the breadth of nineteenth century scientists, who aimed for theories encompassing the total organism.

Pioneers

Little systematic work was conducted on the processes of aging during the latter part of the nineteenth century and the beginning of the twentieth century, the years in which psychology became established as a separate discipline. In addition, the subdiscipline of developmental psychology turned out to be child

psychology. However, a few early pioneers in the study of child development did turn their attention to the psychology of aging later in their careers. Among these were G. S. Hall, Charlotte Bühler, Carl Jung, and Walter Miles.

In 1922, Hall published *Senescence: The Second Half of Life*. He summarized what was known about aging in several scholarly fields, but it can be looked upon as the beginning of a focus on the psychology of aging. *Senescence* was a broadly conceived book in which Hall reviewed the evidence about aging from all contemporary sciences and the general literature at the time (e.g., physiology, medicine, anatomy, philosophy) and something of the humanistic content about the psychology of the aging adult, in particular, the psychological issues of death. For Hall, the experience of aging was a matter of walking up the hill of life toward maturity and then walking carefully down the other side toward old age.

Charlotte Bühler began publishing articles on child developmental psychology during the 1920s and produced her original book on the course of human life in German in 1933. Relying upon diverse material (biological and psychological studies, production and performance records, biographical and autobiographical material), she laid the foundation of what later has been called life span developmental psychology. While Buhler emphasized the psychological processes of development and aging, she considered them in conjunction with the biological life cycle. The underlying biological structure of life provided a ground plan of growth, maintenance, and decline as the basis of psychological expansion (development) and restriction (aging).

From the beginning, psychoanalytic theory has been a developmental theory only for childhood and adolescence. Yet there was an exception in Swiss clinician Carl G. Jung, who in 1933 described stages of development in adulthood, assuming maturational processes of the adult person to account for stage change. Jung's focus was on exploring the self over the life span. He noted a transformative shift from extraversion to introversion in middle and later life: the later years are not a simple addition to youth, but have their own purpose and significance. Due to this perspective, Jung accepted older patients for psychotherapy as well.

The first laboratory of psychology devoted to the study of aging was founded in 1927 at Stanford University. At that time a good amount of research had already been completed on age differences in psychomotor skills and sensory capacities. By 1931 Walter Miles was able to publish a review on the psychology of aging, *Measures of Certain Human Abilities throughout the Life Span*, and in 1933 he followed it with a longer paper on life span changes. Miles directed most of his attention to psychomotor functions and was led to distinguish motility, i.e., the speed of motor movements, from the speed of simple reaction. For historical reasons, the research at Stanford was not continued when Miles left in 1933 for Yale University.

Concepts of Aging

Theory, Model, and Metaphor

Before reviewing specific psychological theories of aging during the time period following World War II, it is instructive to elaborate on a few theoretical concepts. Recall the classic dictum that there is nothing so practical as a good theory. A theoretical framework helps the scientist to accumulate and integrate data into a body of knowledge, as well as to provide directions for new research. Recently, several researchers in gerontology came to the conclusion that the psychology of aging is data rich, but theory poor. This conclusion, of course, depends at least partially on the definition of the term theory.

Under the influence of logical positivism, it has been assumed that proper theory development is identical with theory formalization in terms of logically linked mathematical propositions. From this view, attempts to develop formal (i.e., rigorous, precise, and at least potentially quantitative) theories in the psychology of aging have not been very successful. Almost imperceptibly, the attention of researchers turned to the formalization of models, which – generally speaking – are regarded as more simple and quantifiable than theories, but which also focus on limited aspects of aging.

Formalization in terms of quantitative models (or theories, for that matter) ignores the constructivist view that science is in an essential way metaphorical or characteristically employs metaphors. In fact, models are extended and systematic metaphors. For instance, before World War II, most researchers in intellectual abilities adopted the model of decline with age, i.e., intellectual abilities declined just as functions of the physical body declined with increasing age. This model is based on the so-called hill metaphor, introduced by G. S. Hall in 1922, describing development going uphill and aging going downhill.

The hill metaphor is still alive to this day, and so are many other metaphors, hidden in the disguise of some model or theory. This explains why the terms theory, model, and metaphor are often used interchangeably in the literature. Briefly summarized, the relative significance of these terms can be phrased as

follows: the metaphor drives the theory in the psychology of aging in the first place, and the model functions as a more general, extended, or systematic kind of metaphor, which connects theory with empirical research. In the following, the term theory should be understood in the broadest sense of the word.

Psychology of the Aged

Research in the psychology of aging has been guided by a somewhat diverse collection of theories, models, and metaphors. Historically, there have been three approaches in this field: the aged, age, and aging. The psychology of the aged focuses on older people and later life. Grounded in a stages-of-life perspective, most studies of the aged demonstrate a thematic, descriptive approach and little coherence. In the research literature, at least 70 different themes can be distinguished, varying from Alzheimer's disease, life satisfaction, widowhood, and retirement to cognition, death, and dying. Most research findings consist essentially of descriptive statements about the organization of behavior in the aged and their social-medical problems. Given the wide variety of themes and findings, the psychology of the aged may be broadly defined as the study of problematic and nonproblematic behavior in the elderly.

The lack of gerontological theory in psychological studies of the aged results from the traditional stability orientation to adulthood, i.e., ordered changes are restricted to childhood and adolescence, while further developments in adulthood are not assumed. It has been shown that the psychological study of the aged is heavily infested with biomedical conceptions of aging as a disease or a result of some deteriorative process. For instance, cognitive processes at older age are often described in terms of failure, loss, insufficiency, inadequacy, impoverishment, decrement, inefficiency, or impaired performance. These biomedical conceptions of aging reflect the dominant metaphor that aging is a biological or medical problem and that the elderly make up a problem group in society.

Psychology of Age

The second approach in psychogerontology is the psychology of age, which focuses on age differences. Most research according to this approach has been cross-sectional, describing and comparing groups of people of different ages measured at the same time. The central research question concerns the relation between age as the primary independent variable and some other variable of interest as the primary dependent variable, e.g., mortality, morbidity, autonomy, quality of life, mental abilities, or productivity. The derived research question often concerns the extent to which intervening variables, such as sociodemographic, environmental, psychosocial, biophysiologic, or lifestyle factors, are related to the observed differences with age.

Cross-sectional age differences are frequently misinterpreted in terms of age changes, aging, or changes in behavior over time. Over the last three decades, however, researchers gradually realized that age differences do not equal age changes, or – to put it differently – that chronological age used as the independent variable does not help to explain, or at most only partially explains, the aging process. In 1965, K. Warner Schaie was one of the first to realize that cohort and period of time may have more productive explanatory properties than age, and, accordingly, he designed the age-period-cohort (APC) general developmental model. However, due to the dependency of these three time parameters upon calendar time (both dependent and independent variables are expressed in terms of the same calendar time), there is always the problem of time confounds, regardless of how data are collected or statistically analyzed.

Another point of view regarding the age variable is based on the conception of age as an index variable that is in need of further explanation in terms of aging processes. Most researchers use chronological age implicitly as a dummy variable or index that stands not for a single underlying aging process, but for a host of processes that independently and in concert bring about changes we recognize as aging. From an experimental perspective, this means that fruitful research will focus on identifying the causes and consequences of the processes responsible for age-related differences. This type of cross-sectional experiments is particularly found in the field of cognitive aging, though longitudinal information is needed to reach more definitive conclusions about the hypothesized aging processes.

Psychology of Aging

The third approach in psychogerontology is the psychology of aging, which, briefly summarized, studies the regular changes in behavior after young adulthood. In order to study changes over time, it is necessary to carry out longitudinal research, which essentially means that the performance of a group of subjects from a single cohort is compared with that group's own performance at other periods in time. In this context, the term aging is often used both as a label for an independent variable to explain other phenomena (e.g., mortality, productivity, health,

competence) and as a dependent variable that is explained by other processes (e.g., wear and tear, genetics).

It should be noted in the preceding definition that the adjective regular in the phrase regular changes in behavior refers to the orderly or typical changes in behavior – or so-called behavioral patterns of change with age – as found in longitudinal research on aging. In the cognitive domain, for example, a general pattern of average declines with advancing age has been reliably established. Within this pattern, however, another classic pattern of cognitive aging can be distinguished, i.e., the relative increase of verbal information with age compared with decline in spatial-perceptual performance.

It is important to note also the implications of the phrase after young adulthood in the preceding definition. Thus defined, the psychology of aging is grounded in the perspective of two stages of life, development and aging, which are usually described as two successive processes of change in time, with the transition point or apex at maturity. As noted before, the classic metaphor for the two stages of age-related change in life is the hill metaphor, which is based on biological conceptions of growth and decline, particularly the so-called mortality curve. Mortality rates are high for infants, regularly decline to a minimum at about age 10, and then rise progressively throughout the remainder of the life span (Gompertz' law). Psychological processes of change, however, do not necessarily parallel biological changes along the life span. For example, fluid abilities such as speed of information processing reflect genetic-biological determinants and tend to decline with age. Crystallized abilities, on the other hand, represent cultural-social influences, e.g., on general world knowledge, and may display some growth with age. This cognitive phenomenon raises the as-yet-unsolved problem of to what extent psychological processes of development and aging are different from each other, as both processes refer to age-related changes.

Classical Theories

Developmental Tasks/Activity Theory

In 1948, Robert J. Havighurst published his much-reprinted book on the concept of developmental tasks in a life span perspective. A developmental task arises at a certain period in the life of the individual, successful achievement of which leads to the individual's happiness and success with later tasks, whereas failure leads to unhappiness, disapproval from society, and difficulty with later tasks. All of these tasks have biological (physical maturation), psychological (aspirations or values), and cultural (expectations of society) bases. Havighurst described the following six developmental stages or age periods, each with its own developmental tasks: infancy and early childhood, middle childhood, adolescence, early adulthood, middle age, and later maturity (beyond age 60). The developmental tasks of later maturity, for instance, can be summarized as follows: (1) coping with the physical changes of aging, (2) redirecting energy to new roles and activities such as grandparenting, retirement, and widowhood, (3) accepting one's own life, and (4) developing a point of view about death. Later on, the central organizing concept of age-related developmental tasks was named activity theory, as opposed to disengagement theory.

Psychosocial Theory of Personality Development

With the publication of *Childhood and Society* in 1950, Erik Erikson made a major contribution to the understanding of personality development across the life span. Erikson formulated a psychosocial theory of eight stages of life, each with its own characteristic crisis that arises out of the conflict between two opposite tendencies. The developmental task of each age period is to resolve its conflict, which requires the integration of personal needs with the demands of society. The successful resolution of each conflict leads to developmental strength in terms of a new virtue. Failure to deal adequately with a task during its period of ascendancy, however, is damaging to personality development. For example, the last stage of life, old age, refers to the opposite tendencies of integrity versus despair. At this point an individual's life either makes sense because of some cross-cultural, human principles or is marked by a sense of despair, because it seems meaningless. The successful achievement of integrity might lead, eventually, to the virtue of wisdom.

Erikson's life stages and their respective age periods, opposing trends (crises), and potential virtues are as follows:

1. Infancy: 0–1 years, basic trust vs. basic mistrust, hope
2. Early childhood: 1–6 years, autonomy vs. doubt and shame, will
3. Play age: 6–10 years, initiative vs. guilt, purpose
4. School age: 10–14 years, industry vs. inferiority, competence
5. Adolescence: 14–20 years, identity vs. role confusion, fidelity
6. Young adulthood: 20–35 years, intimacy vs. isolation, love

7. Maturity: 35–65 years, generativity vs. stagnation, care
8. Old age: 65 + years, integrity vs. despair, wisdom.

Erikson sees development as a function of both individual and cultural factors, hence the description of his theory as a psychosocial theory of personality development. In each stage of life, the social world widens, so that the infant whose society began with a dim image of the first caregiver at last becomes an elder whose view of the world encompasses humanity. It should be noted that – in spite of the seemingly accurate age division – Erikson's stages of life are not tied closely to specific age periods or age-related changes. The early stages are defined in much more detail than the later ones: postadolescence, for example, includes about three-quarters of the life span, but only three of the eight stages. This division reflects the increase in psychosocial variability with age: the developmental tasks of an infant are relatively universal, but the tasks in later life are dependent as much on personal experiences as on general principles.

Counterpart Theory

In 1960, James E. Birren, the nestor of American gerontology, presented a general theory of aging as a counterpart of development. The use of the metaphor counterpart is meant to express the idea that there are latent structures of behavior (emotions, cognitions, and motivations) carried forward from earlier experience that interact with present situations. Aging is viewed as a transformation of the biological and behavioral development of the organism expressed in a counterpart manner in variable ecological contexts.

Observations of old persons suggested that there is a pattern to the changes that occur in late life, which are not merely due to happenstance or chance. In explanation of these late-life patterns of change, Birren noticed that natural selection as an explanatory mechanism was not very obvious since some of the patterns or features in old persons (organisms) do not appear until long after the age of reproduction has passed. He concluded, therefore, that these regularly appearing features (including longevity) must be a consequence of traits that were selected for at the time of reproduction. Briefly summarized, Birren's counterpart theory states that any biologically based order in late-life characteristics must arise in association from counterpart characteristics of development that were subject to pressures of selection.

Birren pointed out that behavioral factors can be involved in the counterpart process, that is, patterning of late-life events could arise via natural selection of long-lived and intelligent persons. For example, although individual differences in longevity do not appear until long after reproduction has been completed, intelligent, long-lived parents are able to provide an environment in terms of food and protection that is favorable for their young to survive. In other words, counterpart theory advocates indirect selection for positive late-life characteristics that embrace a wide range of complex biological (e.g., potential for a long life) and behavioral (e.g., intelligence) characteristics. As such, counterpart theory expanded the classical hill metaphor of development and aging to include questions about their relationships and how behavior comes to be organized over the adult years of life, if not over the whole life span.

Disengagement Theory/Activity Theory

The term disengagement refers to the withdrawal of people from previous roles or activities. Starting from the assumption that people turn inward from middle age on, Cumming and Henry theorized in 1961 that this primary mental process produces (1) a natural and normal withdrawal from social roles and activities, and (2) an increasing preoccupation with self and decreasing emotional involvement with others. In positing the universality and normality of withdrawal, disengagement theory has been criticized for being neither natural nor inevitable. While the theory professes to explain general psychological and social processes of aging, it offers only a one-sided view of the aged, given the significant proportion of older people who do not lose interest in life and do not withdraw from society.

Disengagement theory encouraged the development of an opposing theory of the aged, activity theory, which is based on the concept of development tasks. According to its main proponent, Robert J. Havighurst, activity theory states that in order to maintain a positive sense of self, elderly persons must substitute new roles for those lost in old age. As such, activity theory presents a broader view of older people.

Personality Theory of Age and Aging

In 1968, Bernice L. Neugarten published her classic book of readings, *Middle Age and Aging,* from a life cycle perspective. Starting from a series of studies begun in the 1950s, Neugarten and her associates described the life cycle in terms of two theoretical emphases. The first area of emphasis is the study of timing of transitional events in the lives and roles of individuals. Life events, such as marriage, parenthood, occupational achievement, or retirement, are

normatively scheduled; that is, they are expected to occur within certain ages and in a certain sequence. As such, they lead to changes in self-concept and identity. In metaphorical terms, individuals have internalized a social clock, and age norms act as prods and brakes upon behavior over the life span. However, unexpected events (such as automobile accidents) or age-normative events that occur off time (such as early widowhood) may have negative developmental consequences (e.g., life crises).

The second area of emphasis is the study of personality type as a predictor for successful aging. Aging persons have differing capacities for coping with life stresses and for coming to terms with their changing life situations. Eight different personality types of aging have been distinguished, which Neugarten named the reorganizers, the focused, the disengaged, the holding-on, the constricted, the succorance-seeking, the apathetic, and the disorganized. Briefly summarized, aging is viewed as a process of adaptation in which personality is the key element. The aging individual plays an active role not only in adapting to the biological and social changes that occur with the passage of time but also in creating patterns of life that will give him or her greatest ego involvement and life satisfaction.

Cognitive Theory of Personality and Aging

In 1970, Hans Thomae described briefly a cognitive theory of the aging personality, intended to integrate various biological, sociological, and interactionist perspectives while at the same time focusing upon the psychodynamics of aging. Central concepts in his theory are perception, perceived situation, and perceived self. Thomae postulates, for example, that perceived change rather than objective change is related to behavioral change and that change is perceived and evaluated in terms of the aging person's dominant concerns and expectations. Successful adaptation to age-related changes, then, relates to the maintenance and restructuring of the balance between cognitive and motivational systems, e.g., the balance between acceptance of oneself as old or rejection of this perception, which is one of the developmental tasks of aging persons.

Modern Theories

Life Span Development and Aging

Since the beginning of the 1980s, Paul B. Baltes and his associates have conducted a series of studies on psychological processes of development and aging from a life span perspective. In line with the tradition of life span developmental psychology, development and aging are conceived as synonyms for behavioral changes across the life span. Starting from these studies, Baltes has developed a theoretical framework of seven propositions about the nature of human aging from a psychological point of view: (1) there are major differences between normal, pathological, and optimal aging, the latter defined as aging under development-enhancing and age-friendly environmental conditions, (2) the course of aging shows much interindividual variability (heterogeneity), (3) there is much latent reserve capacity in old age, (4) there is aging loss in the range of reserve capacity or adaptivity, (5) individual and social knowledge (crystallized intelligence) enrich the mind and can compensate for age-related decline in fluid intelligence (aging losses), (6) with age, the balance between gains and losses becomes increasingly negative, and (7) the self in old age remains a resilient system of coping and maintaining integrity.

Based on this framework of propositions, a psychological model of successful aging has been devised, named selective optimization with compensation. The central focus of this model is the management of the dynamics between gains and losses, i.e., a general process of adaptation, consisting of three interacting elements. First, there is the element of selection, which refers to an increasing restriction of one's life world to fewer domains of functioning because of an aging-related loss in the range of adaptive potential. The second element, optimization, reflects the view that people engage in behaviors to enrich and augment their general reserves and to maximize their chosen life courses (and associated forms of behavior) with regard to quantity and quality. The third element, compensation, like selection, results from restrictions in the range of adaptive potential. It becomes operative when specific behavioral capacities are lost or are reduced below a standard required for adequate functioning.

The lifelong process of selective optimization with compensation allows people to age successfully, i.e., to engage in life tasks that are important to them despite a reduction in energy. For instance, the pianist Rubinstein remarked in a television interview that he conquers weaknesses of aging (adaptation) in his piano playing in the following manner. First, he reduces his repertoire and plays a smaller number of pieces (selection); second, he practices these more often (optimization); and third, he slows down his speed of playing prior to fast movements, thereby producing a contrast that enhances the impression of speed in the fast movements (compensation).

Reduced Processing Resources

For some time it has generally been accepted that there is an average age-related decline in cognitive performance. Researchers have advanced several explanations for this aging phenomenon, but so far only the resource-reduction view has found wide support. In this view, aging leads to a reduction in the quantity of one or more processing resources, such as attentional capacity, working memory capacity, or speed of processing. According to Timothy A. Salthouse, a typical exponent of this view since the 1980s, processing resources are characterized by three properties: (1) they are limited in quantity, with a measurable aspect such as quantity or effectiveness of allocation increasing until maturity and then decreasing across the adult years, (2) they enable or enhance cognitive processing such that performance in many cognitive tasks is improved when greater amounts of the resources are available, and (3) they are not local or specific in the sense that they are restricted to a small number of highly similar cognitive tasks, but instead are relevant to a broad range of cognitive processes.

These three properties of processing resources have generated a number of specific theories. They can be classified into three categories, based on the dominant metaphor used in theorizing on resource-reduction: space, energy, and/or time. That is, space limitations correspond to restrictions on the size of the computational or working memory region available for processing; energy limitations correspond to attentional capacity restrictions; and time limitations refer to restrictions imposed by tradeoffs between the rate at which information can be processed and the rate at which it becomes unavailable through decay, interference, or some other mechanism.

In a series of experimental studies, Salthouse and his associates focused on the time metaphor of processing speed as an explanatory construct of cognitive aging. Their findings indicate that processing speed is a fundamental construct in human cognition, linked to explicit changes in neural structure and functioning on the one hand and to higher-order cognitive processes such as reasoning and abstraction on the other. As such, Salthouse hypothesizes that processing speed may well provide the cornerstone for integrative theories of cognitive aging. It should be noted, however, that the resource-reduction view leaves unanswered the fundamental questions of why the reduction in resources occurs, and how that reduction results in lower levels of cognitive performance.

Personality and Aging

Studies of personality and aging reflect the concept of personality, here defined as the set of characteristic dispositions that determine emotional, interpersonal, experiential, attitudinal, and motivational styles. Generally speaking, two theoretical traditions can be distinguished in this field, trait and developmental stage models. In both traditions, the central issue concerns the extent and nature of personality stability and change over the life span, or, to put it differently, the extent to which aging processes per se are responsible for personality change.

Overall, longitudinal studies of personality traits have consistently found structural invariance of personality over time, i.e., a marked pattern of similarity in factor structure across instruments, cohorts, and types and times of measurement. According to Paul Costa and Robert McCrae, typical proponents of the trait model, the same five major factors (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness) have emerged from longitudinal studies using somewhat different approaches. In conclusion of the evidence, they state that people stay much the same in their basic dispositions and show a high degree of stability of personality, particularly during the latter half of their life course.

More recent extensions of the trait model pertain to personality-linked constructs such as locus of control and self-concept. Generalizations about stability and change are limited by the relatively small number of studies available, the large majority of which are cross-sectional in design. However, there is growing consensus that personality traits tend to be stable with age, whereas key aspects of self such as goals, values, coping styles, and control beliefs are more amenable to change.

Theoretical models of adult personality development represent the second tradition in the personality and aging field. Two theories, developed by Erik Erikson and Daniel Levinson, respectively, offer developmental stages beyond the period of early adulthood. As discussed previously, Erikson's eight stages, extending from infancy to old age, were formulated more than 55 years ago. From this perspective, it is surprising that only limited empirical evidence has been collected for the maturity and old-age stages, i.e., generativity vs. stagnation and integrity vs. despair. There are no longitudinal studies, for example, that ask whether the achievement of generativity in midlife is a necessary precursor for the achievement of integrity in the later years. Erikson's theory deserves more critical attention from gerontologists.

In Levinson's theory of personality development (based on a series of in-depth interviews with 40 men), each man's life structure goes through an orderly sequence of periods that alternate between stable phases and transitional phases, which are generally crucial turning points in life. Beginning with a transition out of adolescence (17 to 22 years), there are three major periods: early adulthood (ages 17 to 45), middle adulthood (ages 40 to 65), and late adulthood (past age 60). The periods overlap because each is bridged by a 5-year transition that is part of both periods. The timing and length of each period and the development that takes place within it vary from man to man depending on the biological, psychological, and social conditions of his life. Nevertheless, a close linkage of periods with age intervals is suggested. Levinson's theory can be severely criticized on many grounds, of which the impossibility of replicating the in-depth interviews poses the most serious problem.

Behavioral Genetics and Aging

Behavioral geneticists of aging are concerned with the extent to which hereditary factors influence age-related changes over the life span of the individual. Here, heritability is defined as a descriptive statistic referring to the portion of observed, phenotypic variation in the population that can be accounted for by genetic differences among individuals; the rest of the variation, the non-genetic portion, is called environmental. Thus, change in heritability over the life span indicates that the relative roles of genetic and environmental influences can change with age in terms of their effects on biological and behavioral differences among individuals in the population.

With regard to the issue of stability and change, Nancy L. Pedersen and Robert Plomin, two leading researchers since the 1980s, make a distinction between phenotypic and structural stability. Phenotypic stability, as expressed in the familiar correlation between the same measures on successive occasions, refers to the stability of both genetic and environmental components. Structural stability, on the other hand, refers to either genetic or environmental invariance (stability) throughout the life span. Given this distinction, Pedersen states that theories of aging that rely on the demonstration of genetic variance only as support for claims of phenotypic stability need to be modified to incorporate findings of both genetic and environmental involvement in stability. For example, early predictions of cognitive performance with age suggest that changes in phenotypic variance would reflect changes in environmental variance only, while assuming implicitly genetic stability. However, as the Swedish Adoption/Twin Study of Aging (SATSA) has shown, no simple explanation exists for changes in variance of cognitive performance with age: increases in phenotypic (total) variance resulted from increases in environmental experiences, whereas decreases in total variance were distributed equally among genetic and environmental components.

Theory formation in gerontological behavioral genetics is still in its infancy. On the basis of recent analyses, however, Pedersen comes to the following tentative conclusions: (1) the relative importance of genetic and environmental effects on individual differences in the elderly is phenotype specific. Heritability is low to moderate for personality traits and measures of well-being, moderate for health-related phenotypes, and greater for cognitive abilities, whereas heritability for memory is lower than that for verbal and spatial abilities or perceptual speed. (2) There are age differences in heritability, the pattern of which is phenotype dependent. For some measures, particularly health-related characteristics, the relative importance of genetic effects appears to decrease across age groups. For others, heritability is stable, increases, or reflects an inverted L-shaped function. Variance changes may reflect an increase of either environmental or genetic influences, depending on the phenotype. More often, environmental effects account for the increase in variability in health-related phenotypes. (3) Across short spans of time, genetic effects are more stable than environmental effects for personality and cognition. Environmental effects of importance for individual differences late in life are changing. Nevertheless, environmental influences are at least as important for phenotypic stability across short (3–6-year) spans of time.

New Theories

Gerotranscendence

In 1989, Lars Tornstam suggested that human aging, the very process of living into old age, encompasses a general potential toward gerotranscendence, i.e., a shift in meta-perspective from a materialistic and rational vision to a more cosmic and transcendent one, normally followed by an increase in life satisfaction. On the basis of qualitative and quantitative studies, Tornstam developed the theoretical concept of gerotranscendence at three levels of age-related, ontological change: (1) the cosmic level, for example, changes in the perception of time, space, and objects, increase of affinity with past and coming generations, changes in the perception of life, disappearing fear of death, acceptance of the mystery dimension in life, and increase of cosmic communion

with the spirit of the universe, (2) self, for example, discovery of hidden – both good and bad – aspects of the self, decrease of self-centeredness, self-transcendence from egoism to altruism, rediscovery of the child within, and ego integrity, (3) social and individual relations, for example, less interest in superficial relations, increasing need for solitude, more understanding of the difference between self and role, decreasing interest in material things, and increase of reflection.

The new theory of gerotranscendence is reminiscent of the classical concepts of disengagement (Cumming and Henry) and integrity (Erikson), but differs qualitatively in some aspects. For example, gerotranscendence implies a redefinition of reality, while disengagement is restricted to turning inward; also, gerotranscendence is connected with social activity and a need for solitary philosophizing at the same time, while disengagement encompasses social withdrawal only. Next, gerotranscendence refers to offensive, multicoping strategies, while disengagement implies defensive coping strategies and social breakdown, and, finally, Erikson's integrity refers primarily to the integration of elements in life that has passed, while gerotranscendence implies more of a forward or outward direction, including the redefinition of reality. In summary, even though Tomstam's theory of gerotranscendence is based on limited empirical evidence, it nevertheless makes a promising attempt to integrate and further develop some classical and modern psychosocial theories of aging.

Branching Theory

In 1995, Johannes J. F. Schroots presented a brief outline of a dynamic systems theory of aging, called gerodynamics. This comprehensive theory *in statu nascendi* is based on general systems theory, notably the second law of thermodynamics, and dynamic systems theory (chaos theory). The second law states that there is an increase of entropy or disorder with age in living systems, resulting in the system's death. Chaos theory postulates that internal or external fluctuations of dynamic, far-from-equilibrium systems can pass a critical point – the transformation point – and create order out of disorder through a process of self-organization, that is, a process by which a structure or pattern of change emerges with the passage of time. From this meta-theoretical viewpoint, the aging of living systems can be conceived as a non-linear series of transformations into higher- and/or lower- order structures or processes, showing a progressive trend toward more disorder than order over the life span, and resulting in the system's death.

Gerodynamics lies at the root of a new aspect theory of aging, called branching theory. The basic principle of this theory is the bifurcation or branching behavior of the individual at the biological, psychological, or social level of functioning. Metaphorically speaking, bifurcation means that the fluctuating individual (organism) passes a critical point – the bifurcation, branching, or transformation point – and can branch off into higher- and/or lower- order structures or processes. Higher- and lower- order structures can be translated in terms of mortality (probability of dying, life expectancy), morbidity (disease, disorder, disability, or dysfunction), and quality of life (well-being, life satisfaction). For example, traumatic life events and a healthy lifestyle may result in lower- and higher- order structures, respectively, and consequently in higher- and lower-probabilities of dying. It should be noted, however, that lower- order bifurcations at the biological or psychological level of functioning (e.g., illness or divorce) do not always result in lower- order branching behavior, that is, some people are strengthened by illness, and divorce may have a positive rather than a negative effect on mental health in terms of life expectancy and quality of life. Briefly summarized, branching theory requires the study of determinants and patterns of branching behavior across the life span. It remains to be seen how empirical research lends support to its theoretical claims.

Life Course Dynamics

As noted previously, development and aging are traditionally thought of as two successive processes of change, with development conceived as an incremental process like biological growth, and aging as a decremental process like senescence. The old-fashioned calendars of life, with people of all ages arranged in order of age on a platform, are an excellent illustration of the hill or pyramid metaphor, with rising and declining steps. Essentially, this metaphor views the human life course as a single-peaked function with the apex varying across the life span, dependent on the biological or psychological function in question.

The notion has been growing that psychological processes of change do not necessarily closely parallel biological changes along the life span. The differential course of fluid and crystallized mental abilities may serve as an example. The life span patterns of both abilities show a rapid rise until early adulthood, followed by a period of relative stability for the crystallized abilities until the age of 60 years, but a slow decline of the fluid abilities after early adulthood. The as-yet-unsolved problem in the

psychology of aging, then, concerns the diachronic (successive) and synchronic (simultaneous) relations of development and aging.

Recently, a dual process theory of life course dynamics has been developed that might help to explain the differential decline of fluid and crystallized abilities in terms of varied sensitivities for neural processes of growth and senescing. Generally, the growth of the central nervous system (CNS) comes to a stop in early adulthood, while the aging of the system or neural slowing continues increasingly. As crystallized intelligence is primarily based on the full-grown storage capacity of the CNS, which has enormous reserves, crystallized abilities are less dependent on neural slowing than fluid abilities, which are primarily related to speed of information processing or neural slowing, rather than to informational capacity. In other words, the life span patterns of crystallized and fluid abilities are minimally determined by two fundamental, synchronic forces, growth (development) and decline (aging), which produce – in combination and with varying rates – the differential course of fluid and crystallized abilities. Computer simulation studies might show that the simultaneous forces of growth and decline explain the course of other psychological functions and abilities as well.

Prospects

Psychological theories of aging deal with one of the most complex issues science can face, that is, how behavior becomes organized over the course of an individual's life. A theory of aging that integrates changes in cognitive and personality functions awaits development. From dynamic systems theory, it has become clear that adaptive self-stabilization and maintenance with age in the face of environmental challenges calls for increases in complexity of organization and that such complexity carries a price: the more complex the adaptive process, the less stable the individual and the more energy it must disperse in order to stabilize and maintain its complexity. The overall picture, then, is that aging both causes and reflects the increasing variability of individual functioning.

As clarity emerges about what is being explained of complex behavior, it becomes evident that chronological age as a causal or explanatory variable needs to be replaced and/or supplemented by other variables more sensitive to intra- and interindividual differences. Recent studies of development and aging show that the combination of chronological age with variables reflecting directly or indirectly the length of life or the residual life span offers a promising perspective for theoretical progress.

Human individuals have similar and different genetic backgrounds; they also grow up and grow old in similar and different social and physical environments. Consequently, the general and unique features of the psychological pathways of life call for concepts and theories to identify the causal factors determining the length, context, and personal interpretations of life. In other words, future theories ask for a frame of reference that includes both the organismic and the ecological perspective on life. In this respect, it should be noted that the relative dominance of biological, psychological, or social variables over the life span changes with age; this applies also to their interactions. In the final analysis, there will be an increasing need for theories of aging that are more integrated and inclusive. Dynamic systems theory and computer simulation might offer tools to deal with the issues of complexity and integration.

See also: Attention; Behavioral Genetics; DNA and Gene Expression; Information Processing/Cognition; Life Course; Life Span Theory; Memory; Personality; Psychological Well-Being; Time: Perceptions and Concepts.

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Theories of Aging: Social

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Glossary

Age Stratification Perspective – A theoretical approach that focuses on the progression of birth cohorts through the age strata of a society and that views the age stratification system as changing in response to cohort characteristics and other social phenomena.

Disengagement Theory – Theory arguing that successful aging involves a mutual withdrawal of the aging individual and society. This is seen as functional for society and beneficial, normal, typical, and ideally voluntary on the part of the individual.

Interpretive Theory – Theory that assumes that individuals have significant freedom of action or choice and that emphasizes that humans are capable of creating and using symbols.

Modernization Theory – Theory arguing that as societies modernize, industrialization, urbanization, new technology, improved health, and longevity contribute to a decline in the social status of the aged.

Political Economy Perspectives – A range of theoretical viewpoints that emphasize the importance of power and economic forces in the structuring of society and the life chances of individuals.

Introduction

Social gerontology draws on a broad array of theoretical perspectives and social theories from several disciplines, but rarely has it developed its own interdisciplinary theories or theoretical perspectives. By theoretical perspective, we refer to an articulated set of concepts held to be important for the understanding of a social phenomenon. In essence, a perspective says, 'look at this,' whereas theories provide a meaningful interpretation and a background of assumptions about the way the social world works, grounding the individual concepts and their postulated linkages.

There is not, and probably should never be, an overarching theory of aging. Aging is living, and it is doubtful that any attempt to construct such a theory would be capable of capturing all the dynamics of all aspects of life. Rather, there are theories in aging. There have been some attempts to systematically and logically relate hypotheses, based on precise conceptualization, to understand specific phenomena in relation to aging. Such phenomena cover a wide range of specific areas, including work and retirement behavior, economic security, changes in health and health-care utilization, family life, and social integration. Questions about theory in this sense have to do with the empirical validity of theories in aging or, more often, with the empirical validity of models that are not well theorized. In contrast, most theorizing is directed to the articulation of theoretical perspectives and their applicability to social processes of aging, the social status of the aged, and the ways in which social institutions are shaped by, adaptive to, or reactive to changes in the age structure of societies. There would be little to say if we were to confine attention to formal theories. The first section of this article therefore presents a framework to describe different theoretical perspectives that are or have been used in social gerontology. This framework will allow us to contextualize major developments in the history of theorizing in social gerontology, as well as current theoretical approaches. A final section considers major challenges for social theorizing in gerontology.

A Framework to Classify Theory

Explicit discussions of theory in social gerontology have taken many forms. Most commonly, scholars contrast two different approaches, such as structural-functionalist versus political economy approaches or feminist versus masculinist theorizing. More comprehensive classifications of social theories of aging have taken several approaches. Bengtson *et al*. describe social science theories used in aging as rooted intellectually in symbolic interactionism, structural functionalism, Marxism, economic rationalism, hermeneutics, and postmodernism. Their gerontological applications include activity theory, disengagement theory, modernization theory, subculture theory, continuity theory, social breakdown/labeling theory, exchange theory, political economy of aging, social constructionism, life course and feminist theories, and critical gerontology. Other classifications have a similar list but describe the temporal relationship among theoretical perspectives differently. That is, they tell different stories about how theory developed in social gerontology.

Our approach is loosely narrative, distinguishing early and emergent theorizing, but it rests on a typology articulated by Marshall that distinguishes two major axes of social theory: the normative-interpretive dimension and the micro-macro dimension. The micro-macro dimension describes whether the theoretical approach focuses on social psychological processes at the level of the individual in social interaction, focuses on social institutions or large-scale aspects of social structure, or tries to link individual and small-scale social interaction in the context of social structure and macro-level social processes. The normative-interpretive dimension classifies approaches ranging from those that give little attention to human autonomy and meaning-construction to those that view the individual as a voluntaristic actor who at least attempts to exercise choice. Theoretical perspectives (and the rare actual theories in the field) can be classified along these two dimensions.

The Legacy of Early Theorizing

Early theorizing in social gerontology attended to both micro- and macro-level concerns, but primarily from a normative or deterministic perspective. From the beginnings of serious social theorizing around 1940, there was a concern for an alleged decline in the extent to which older people were integrated into society. This concern was expressed principally by structural functionalist sociologists, who view role as the key building block of society. Social integration was defined as embeddedness in role relations, and large-scale social changes were thought to cause declines in social integration with aging. From its origins, social gerontology thus took as problematic the 'fit' between the aging individual and society, but it failed to adequately describe the structuring of life experience by class, gender, and similar structural properties, let alone age structure. These early attempts were predominantly normative. Theorists developed interpretive approaches to understand aging, in part, as a reaction against the earlier normative approaches.

The Early Focus on Adjustment

The history of social gerontology has until recently been largely an American history and has been influenced by America's ideology of individualism. As Shanas (1971: 159) has noted of early social gerontology, "Current American sociological interest in the aged …. can be traced directly to the efforts of Ernest W. Burgess as a member of the Committee on Social Adjustment of the Social Sciences Research Council". For Burgess, the modernization of society had led to the loss of many significant roles for the elderly to play, leading to the so-called 'role-less role of the aged.' This phenomenon was subsequently addressed through functionalist role theory investigating the adjustment of the aging individual to changing social roles or the loss of roles, with the dependent variable being some form of adjustment. Burgess saw this as a problem of a lack of fit between the individual and society that could be remedied either by societal change or by individual adjustment, but the field primarily focused on the latter. The Committee on Social Adjustment report was published in 1948 under the title, 'Social Adjustment in Old Age.' The program of work funded by the council supported activities at the Institute for Human Adjustment at the University of Michigan (from which derived the field-defining handbook edited by Tibbitts in 1960 and the work of Cavan and associates at Chicago, leading to the landmark, *Personal Adjustment in Old Age*, published in 1949).

Modernization Theory

Early research pursuing this theme of adjustment at the macro level dealt with modernization and its allegedly detrimental effects on the social status of the aged person. Both society and the individual were poorly theorized in most of this work – the individual was largely ignored in this macro-sociological research area, and critical scholarship eventually showed that work in the area failed to adequately place societies within a world socioeconomic system and failed to recognize the complexities of societal modernization processes. While Burgess presented specific statements about the relationship between modernization and the social status of older people, Cowgill progressed from an initial list of 22 independent propositional statements to a logically related set of four causal pathways through which modernization acted to reduce the social status of the aged. The major aspects of modernization, in his theory, were advances in health technology, economic technology, urbanization, and education. The theory suggested that each led, through intervening variables, to lower status of the aged. For example, urbanization led to migration of the younger generation, neolocal marriage, and residential segregation, which removed the younger generation from the authority of their parents, leading to lower social status.

Problems with the approach include its assumption that modernization is a uniform process, empirical problems with timing (for example, there are many historical cases in which retirement emerged prior to economic modernization), the assumption that older people historically had higher status in premodern

societies or that they have it in contemporary societies that have not modernized, and an unclear conceptualization of social status. For example, if government allocation of resources to the aged is a sign of status, then clearly the modern industrialized welfare states accord historically unprecedented status to the aged.

Through Cowgill's efforts at formal theory construction, the theory of aging and modernization served as a useful reference point for researchers precisely because it could be tested, and this led to extensive qualification and substantial rejection of the theory. To a great extent the theory served as a foil, stimulating a reactive development of theorizing in the political economy tradition.

Role Theory, Disengagement Theory, and Activity Theory

The modernization and aging theory is one of two major formal social theories of aging. We now consider disengagement theory, the most important formal theoretical approach at the micro or social psychological level, although it did have a social structural component and was explicitly formulated as a theory about the link between the individual and society. Its formalization included nine postulates and several explicit corollary statements. Its major premise was that, with aging, there was a mutual severing of the ties between the individual and society, and that this was a good thing for both. Social structural change is defined as disengagement if it involves "a thinning out of the number of members in the social structure surrounding the individual, a diminishing of interactions with these members, and a restructuring of the goals of the system" (Cumming and Henry, 1961: 37). Engagement is measured by a count of social role occupancy, a subjective rating of the amount of time spent in normatively governed interaction with others, and an actual count of the number of interactions. Social structure in this structural-functionalist view is conceptualized as a complex system of interlocking status positions, to which role expectations correspond. Social integration during this period of theorizing was equated with adaptation of the older person to society, and adaptation in turn was considered to be indexed by life satisfaction, morale, or happiness. The structural-functional theoretical foundations of this work saw the individual as nothing other than a bundle of roles, spiced with some need dispositions and personality characteristics. In this conceptualization the individual was largely reactive – either to societal demands or to presumably inevitable and universal pressures of physiological and psychological development.

In the general research program from which the disengagement theory was developed, and the subsequent social psychological emphasis on adjustment, the major independent variables entered into models to predict variability in life satisfaction were dispositional or personality factors, or were largely restricted to three domains: health, income security, and social integration. These, in turn, were largely unexamined variables. Few scholars theorized about the causes of variability in health, wealth, or social integration, and no one studied this topic from a life course perspective. To do so would have shifted attention away from the social psychological level toward a social structural level of analysis and required people working with cross-sectional data to think longitudinally. Moreover, to do so would have been a stretch away from the overall individualistic bias of the social sciences in North America.

Activity theory was invented by Cumming and Henry as a foil for their presentation of disengagement theory. They asserted that it was an implicit theory. The response to disengagement theory led to more formal explication of the activity theory by Havighurst *et al.* using data from the Kansas City studies and by Maddox and other scholars using data from the Duke Longitudinal Survey of Aging. The debate was joined by other American social gerontologists and dominated gerontology conferences and publications for many years. More developed theoretical formalization and testing was conducted by Lemon *et al.* and by Longino and Kart. The results, overall, favored activity theory in that life satisfaction was more often found to be associated with higher levels of social integration (measured by a role count) than not. Personality factors were found to be in play. The most damning critiques of disengagement theory argued that much disengagement from social roles was involuntary, occurring, for example, through widowhood and retirement. For all its faults, disengagement theory at least tried to be a theory, but it was not precisely conceptualized, making it difficult to test.

We have grouped activity and disengagement theory into the category of role theories because a structural-functionalist conceptualization of role is common to both. Other scholars, without entering this specific debate, used the same conceptualization of roles. Irving Rosow, the most prominent theorist to do so, spent most of his career articulating a functionalist understanding of aging in terms of role occupancy and argued that socialization for role occupancy in old age was problematic for several reasons, including low motivation to learn the role and a dearth of formal teachers or role models.

The Age Stratification Perspective

An attempt to focus gerontological research more squarely on social structure resulted in the development of the age stratification perspective by Riley and a number of colleagues. What is rarely recognized is that this perspective also postulated an explicit link between the individual and society, through the processes of socialization and role allocation.

The main thrust of the age stratification perspective is precisely to develop a conceptualization of age as structure, a social organization of age statuses through which either cohorts or individuals flow as they age. Each stratum in an age stratification system has its own sets of expectations for behavior and rewards for fulfilling these expectations. There are two components to social structure: people (forming the population structure) and roles. The conceptualization is structural-functionalist. Age is seen not just as providing criteria for entry into or relinquishment of roles. Age-related acts are also viewed in terms of the contributions they make to society, and analytic attention can focus on "either the total system of age-related roles, on the complex of roles appropriate to a given age (stratum), or on particular roles as parts either of the total system or of the complex" (Riley *et al*., 1972: 8).

Role allocation refers to "a set of mechanisms for the continual assignment and reassignment of individuals of given ages to the appropriate roles" (Riley *et al*., 1972: 11). Role allocation as a concept has the potential to describe social structure dynamically, but the treatment of this concept is schematic. The age structure is not static but can be changed by cohorts flowing through it. How this change occurs is not well developed within the perspective, which may be because of the general assumptions found in structural functionalism that social systems tend toward equilibrium.

Socialization is a process that "serves to teach individuals at each stage of the life course how to perform new roles, how to adjust to changing roles, and how to relinquish old ones" (Riley *et al*., 1972: 11). In structural-functionalist theory, societal equilibrium is maintained largely through highly efficient socialization, which teaches people to do (and to want to do) what they must do if the social system is to survive. For the most part, early social psychological concerns had seen the individual not in terms of the self but in terms of either personality or need dispositions, or as bundles of roles. And the individual has mostly been viewed as passive or reactive – being socialized, for example, to more or less unwittingly live up to the scripts for behavior that are found in the general culture and transmitted through socialization. Although much of the social psychology emanated explicitly or implicitly from a Parsonian version of structural functionalism, and Parsons expounded a 'general theory of action,' there is little real action in this approach, as others have noted. Insofar as this approach touches on the self at all, it treats the self as object – the 'self concept,' rather than the self as process.

The age stratification perspective is not a theory but rather a loosely structured set of assumptions to guide research. This looseness perhaps increased its survivability, because testing through falsification was never an issue. Rather, the perspective played an important role in directing gerontologists' attention to social structure. Although its conceptualization of social structure may have been too rooted in structural-functionalist thinking to adequately address structured social inequality, it was at least a step in the right direction.

The age stratification perspective survives among some social gerontologists as the 'age and society paradigm,' which represents only a slight modification in emphasis to the age stratification perspective. As Riley noted (1994: 436), "Earlier, we had called it 'age stratification,' but then abandoned that term as overly static, failing as it did to reflect the dynamic aspects of both lives and structures." The evolution of the age stratification perspective into the age and society paradigm encompassed Riley's move to a life course perspective, discussed later in this article.

To summarize our brief historical overview, early theorizing in social gerontology did deal with micro- and macro-level approaches, but largely through the analytic lens of functionalist sociological theory. Early theorizing thus falls well into the normative spectrum on the normative-interpretive dimension. The link between the social structure and the individual is the role, the set of expectations for the behavior of the occupant of a specific status position. Socialization prepares people for role occupancy and enactment, and it is usually assumed that it is successful. (Rosow was an exception, stressing reasons why socialization for old age was rarely successful.) Social structure in this view is nothing but a complex interweave of social roles. As such, this perspective fails to find a place for social structure that would allow it to be seen as constraining or enabling individual behavior, and it fails to give the individual much say as to role performance. Subsequent theorizing has been largely reactive to these problems and has sought to develop a conceptualization of social structure that can deal with macro-level social relations of power, domination, and allocation of opportunities and resources, while at the same time avoiding the fallacy of reification that treats social

structure as if it exists independently of the actions of human beings.

Current Theoretical Approaches

The set of theoretical perspectives currently in use by social gerontologists consists of a mix of some remnants of the early theoretical approaches and others that can be seen largely as reactive to the early approaches. These approaches have been taken at the micro and macro levels but often seek to bridge those levels.

Political Economy Approaches

Since the 1980s, a number of theorists have been elaborating theory under the rubric of the political economy perspective to understand the social circumstances of the aged. The term 'political economy' has come to be used in different ways. Walker's 1981 paper, 'Towards a political economy of old age,' and Townsend's 1981 'The structured dependence of the elderly: a creation of social policy in the twentieth century' were two of the earliest defining statements for the perspective's application in the field of aging. Walker (2005: 816) describes "the origins of the political economy of ageing as an explicit attempt to counteract the then prevailing functionalist paradigm in social gerontology…." A Marxian emphasis on the importance of social class and classlike differences between age groups that experience structurally different life chances is linked to an emphasis on the moral economy, which recognizes that social movements, the political process, and economic processes are shaped by cultural conceptions of legitimacy, equity or fairness, citizens' rights, and moral contracts between the generations (*see* Politics of Aging). The link to processes of aging is made by viewing the life course as socially constructed in light of such economic and moral concerns; this aspect of the perspective draws on Weber's assertion that sociology's task is to understand meaningful patterns of social interaction. For example, political economists might view the category 'old age' as defined by retirement, and retirement as a humanly invented social institution reflecting trade-offs between different parties with at least potentially conflicting interests: workers seeking a citizen's wage, owners seeking ways to exercise more control over their workers, and the state seeking to provide for the welfare of its citizens. Townsend (1981: 9) sets out the domain:

> … society creates the framework of institutions and rules within which the general problems of the elderly emerge and, indeed, are manufactured. Decisions are being taken every day, in the management of the economy and in the maintenance and development of social institutions, which govern the position which the elderly occupy in national life, and these also contribute powerfully to the public consciousness of different meanings of ageing and old age. These are decisions … about the commitment of public expenditure which directly govern the services and benefits of older people. Then there are decisions about employment, wages and taxation, transport, urban planning and housing which have a powerful indirect effect on the situation and standard of living of the elderly.

The contrast with the earlier theoretical perspectives is stark. Note the emphasis on the social construction of the social problems of the aged, and also how these concerns focus more on the material conditions of life than on people's feelings of life satisfaction or their social status. Walker makes a similar argument and suggests that the starting point for a political economy of aging should be the relationship between age and the labor market. Myles also calls attention to what Townsend called 'indirect' effects, suggesting that the impact of public policy on the aged is more of a latent function or unintended consequence than something deliberately intended to marginalize the aged. Guillemard points to the importance of ideology and argues that the state fosters ideologies (such as the ideology of '*le troisieme age*') as a means of social control.

We mentioned earlier that much political economy theorizing was reactive to the modernization theory of aging. Aboderin has brought political economy principles to bear in her systematic critique of the modernization theory of aging, during the course of which she may well have given it new life. In a series of papers, she has critically reviewed the literature as it focuses on declines associated with modernization in the extent of kin support provided to the aged. While the modernization and aging theory would suggest that modernization leads to declines in adherence to norms of filial obligation and these in turn lead to declines in material support for the aged, Aboderin's multigenerational research in Ghana supports a much more textured argument that emphasizes materialist (and thus political economy) causes of declining support, but interwoven with factors already considered in the earlier modernization literature (2004b: S136):

> … the identified processes of change clearly suggest that it is the alteration in families' material circumstances that has been the dominant driver of the shifts in support norms and patterns. However, a wholly materialistic explanation is not enough: Changes in broader societal values and ideas have played a role. They have interacted with deteriorating material conditions and serve to exacerbate their effect…. The value that younger and older generations now place on self-reliance, away from

> support by children or kin, is, above all, a response to the worsening economic situation. The principle, it seems, is that if material conditions change to such an extent that fulfillment of a particular family norm becomes harmful to the younger generation, it is no longer tenable and must change.

As Walker notes, the approach furthers our understanding of social structure, which acts to either enable or constrain agency. Agency is not denied, but rather is placed in a context that allows one to theorize the relationships between action and structure or self and society. Walker (2005: 833) makes a persuasive case that the major shortcoming of political economy theorists so far has been to neglect the importance of globalization: "An international political economy of ageing is needed to understand current national and global responses to ageing; to highlight the roles of transnational corporations and IGOs; to critically evaluate globalization and responses to it as they affect older people; to counteract the ideology of the ageing crisis; and to combine agendas that have existed for too long in separate pigeon-holes: human rights, development and ageing."

Walker (2005: 815) states that "The political economy perspective quickly became the key paradigm in social gerontology." But this is surely not so, as any examination of the major social gerontology journals will attest. While most articles found in such journals are atheoretical, those that invoke theory are much more likely to invoke social constructionist, life course, and exchange perspectives than the political economy approach. Walker's view may be shaped by his embeddedness in European gerontology, in which political economy approaches are much more commonly used. Nevertheless, the political economy perspective is increasingly used not only by European social gerontologists but also by those in North America in contemporary research on income security, health care, and a number of other issues (*see* Politics of Aging). In addition, the political economy perspective is so strongly foundational to the newly fashionable critical theory perspective in social gerontology that it is hard to tell the difference.

Critical Theory Approaches

Critical theory has been an important strand of general social theory for almost a century, but it has gained currency in social gerontology only since the 1980s. It builds upon and beyond political economy approaches, drawing on "a number of feminist, discursive, and micropolitical issues typically neglected in formal political economy treatments" (Katz, in press; see also Phillipson and Walker, 1987). Critical theorists critique positivism and strive for reflexivity, an awareness of the social conditions of their theorizing. The leading contemporary critical theorist Jurgen Habermas emphasizes the importance of free communication and forms of practical and emancipatory discourse that are distinct from the rationality of technical discourse. In gerontology, Moody calls for a hermeneutic gerontology, drawing on the humanities as a resource, but he also sees the need for emancipatory knowledge to ensure that our hard-gained technical and practical knowledge will not be misused for domination and exploitation. It is thus important to recognize that critical theorists advocate theorizing for emancipation, not simply for understanding. This political commitment is distinct from most theorizing in social gerontology, which is motivated by the quest for understanding alone, and also from most atheoretical research in the field, which is primarily concerned not with emancipation or understanding, but rather prediction.

Some scholars see 'the new critical gerontology' as the political economy perspective carried to its logical extensions, with the inclusion of feminist theory and cultural studies. Minkler sees critical gerontology as bringing together the political economy of aging and a more 'humanistic path.' These distinctions are not clear and are not accepted by all political economists. We argue that the political economy perspective has room for the emancipatory project of critical theory. Critical theory, like the political economy perspective, is in a sense Marxism in disguise. The early critical theorists were Marxists preoccupied with the development of the class structure and its impact on individual psychology who brought to their theorizing perspectives on human nature and individual behavior from the phenomenologist Heidegger, the psychoanalyst Freud, and others. Later critical theorists in the Frankfurt school turned to pragmatism and symbolic interactionist thinking. They drew on the cultural sciences to further understand the cultural conditions under which people accepted capitalism, and the alienation of the individual resulting from the 'civilization process' and the application of 'instrumental rationality.' It is not at all surprising that some of the political economy theorists, such as Minkler, Phillipson, and Walker, at least sometimes invoke 'critical theory' to describe what they are now doing.

Interpretive Sociology: Social Constructionism, Symbolic Interactionism, and Phenomenology

Even during the early period of social gerontology research, a number of researchers drew explicitly on strands of interpretive theory rooted in symbolic

interactionist and phenomenological sociology as well as symbolic and cultural anthropology to understand aging and the life course. These approaches emphasize that the human being is a symbol-creating and symbol-using creature who actively seeks meaning and seeks to develop lines of actions in order to realize individual interests or motivations. Human behavior, in this view, is seen as constrained, but not fully determined, by biological or social structural factors. Structural-functionalist equilibrium assumptions are rejected, as is strong determinism. This view is wholly compatible with the political economy perspective. The challenge is to theorize the ways in which people struggle to make their lives.

Chappell and Orbach systematically explore the symbolic interactionism of Mead and its applicability to guide research in aging. They highlight the importance of Mead's conceptualization of temporality, his concept of the 'problematic situation,' and his focus on the uniqueness of the individual. We live in the present, but our present influences the ways in which we construct both our past and our future. Mead's perspective stresses constant change, novelty, and emergence in response to problematic situations. The self is not an object or thing, but a process. Chappell and Orbach emphasize that this view of the self is quite at odds with that of many other sociologists who have dealt with aging, including Riley and Rosow.

Continuity theory was developed in a series of works by Atchley. In his most elaborated formalization, he articulated nine specific assumptions and five propositions. The key proposition is perhaps that "Continuity of general patterns of thought, behavior, and relationship is the first strategy people usually attempt to use to achieve their goals or adapt to changing circumstances" (Atchley, 1999: 101). Atchley states that the theory, while a "feedback systems theory," is constructionist, and his description is a good general portrait of the social constructionist perspective (1999: 98):

> It assumes that in response to their life experiences, people actively develop individualized personal constructs…. ideas of what is going on in the world and why…. Continuity theory posits that our personal constructs are influenced by the social construction of reality we learn from those around us and from the mass media, but are not determined by them. No matter how strongly society's efforts to influence personal constructs, individuals ultimately are free to decide for themselves how to construe their personal reality. An important implication of this aspect of the theory is that subjective perceptions of continuity become more theoretically relevant than researchers' perceptions of objective continuity.

Gubrium has made a sustained contribution to the interpretive perspective on aging with his phenomenological and narrative theorizing. His approach can be illustrated from the distinction he makes between the life history and the life narrative: "… the life history is an objective record of the person's past, while the life narrative is the subjectively constructed life" (Gubrium, 1993: 178). When narratives are generated through interviewing, they are viewed as joint constructions or narrative collaborations between respondent and interviewer. In his study of life in the nursing home, Gubrium sees residents as acting the 'resident role' within their individualized horizons of meaning, constructing 'worlds of their own' within organizational parameters and constraints.

Running through this account of social theories of aging is a concern to adequately theorize the relationship between the micro and macro levels of analysis. Interpretive sociologists view the micro-macro linkage in terms of the relationship between self and society, and they see this link as resting on negotiation. Most theorizing in this area has been inductive and based on ethnographic or otherwise qualitative data analysis, which focuses on individuals negotiating a number of transitions in the aging process, such as transitions into age-homogenous environments, chronic illness, widowhood, or impending death. Marshall has presented a set of 13 propositional statements rooted in the interpretive perspective to move toward a theory of aging and dying, but in general there is little formal theorizing within the interpretive perspective at the micro level. This is also true when the perspective is employed to interpret macro-level social structural or institutional processes, as in much of the political economy and critical theorizing discussed previously.

The Life Course Perspective

The life course perspective, in its own varied manifestations, encompasses many of the perspectives previously discussed. There are several different, albeit related, approaches within the life course perspective, and there are also many researchers who describe their work as 'life course' when it does not incorporate some of the key assumptions of that loosely defined perspective. In North America, scholars draw most heavily on the systematic articulation of 'principles of the life course perspective' by Elder, Jr., who has done more than any single scholar internationally to develop the perspective and apply it empirically in aging research, but he acknowledges several precursors, and other exemplars in North

America and beyond take a somewhat different approach.

The North American version of the life course perspective is generally more confined to social psychological rather than social structural domains, or dealing with the linkage between self and society. There has been progressive theoretical formalization since Mills established an imagery for the perspective, arguing that the sociological imagination seeks connections between personal troubles and public issues, or biography and history. Cain, Jr. (1964: 273) sought "to identify, isolate, and systematize a life course, or age status, frame of reference" in an extensive essay, 'Life course and social structure,' published in 1964. However, Riley crystallized what she called the 'emerging life course perspective' in 1979 under 'four central premises,' in which she argued that aging is a lifelong process that starts at birth, really three interacting sets of processes at the biological, psychological, and social levels, and that people's lives affect the social structure of the life course just as that structure influences their lives. In many publications, Elder subsequently codified the perspective in five principles, going beyond Riley to stress the importance of timing of life transitions in relation to historical events, as well as the principle of 'linked lives,' which insists that we view people's lives as interdependent. Finally, Elder gave more importance than Riley to a principle of 'human agency,' asserting that individuals construct their own life course through their own choices and actions, although in the context of opportunities and constraints of history and their social circumstances.

A few North American life course researchers have paid more attention to social institutions and the way they structure the life course in the area of family and work and variability in economic security. However, a significant body of theorizing about the life course at the macro or social structural level is found principally in Europe. European scholars in the life course perspective systematically analyze how the state functions, along with other social institutions such as industry, to create a life course structure in which age is one basis of social inequality interacting with gender and social class. The role of the state is almost completely ignored by North American life course and aging scholars, who have also underconceptualized social structure; however, in Canada there is an ongoing significant attempt by a consortium of government agencies to articulate a life course perspective that will support public policy development.

Both European and North American life course and aging scholars have attended to micro-level phenomena, but in North America this has meant largely specific empirical studies of individual life courses, or types of life courses, examined in terms of the theory of cumulative advantage (perhaps the only formal theory rooted in the life course perspective), which suggests that initial differences in socioeconomic advantage increase over the life course, or the question of orderliness in transitions. In contrast, European life course researchers have generally painted with a broad brush while describing the meaning of biography and career under conditions of social change.

Challenges for Social Theory in Gerontology

We identify three major challenges (of a much larger set) for social theory in gerontology. These are (1) to develop ways to understand the dynamics of self and society and the linkages between micro and macro phenomena; (2) to establish a richer dialogue with general social theory; and (3) theorizing diversity.

Theorizing Self–Society Linkages

The call to achieve a better understanding of the self–society linkage has long been voiced. For example, Marshall and Tindale (1978–9: 169–170) made such a call in a paper, 'Notes for a radical gerontology,' castigating the field for its individualism and neglect of social structure and asserting the following:

> … we believe future research in gerontology has to relate the realities of constituents' lives to the social structure in which they live…. Research moving in this direction takes gerontology away form the focus on personality. We are not arguing against the social psychological concerns of gerontology. Aging is an individual as well as a collective phenomenon. What is needed, we feel, is more research on interpersonal interaction in face-to-face situations, but cast in processual terms, and situating the individual in terms relating to an environment historically understood. Also needed are more studies of the political economy of aging, which will restore a sense of context to our understanding of the lives of today's aged, and especially inform us concerning the socio-economic forces influencing the psychological processes of aging.

Marshall and Tindale were here influenced very much by Mills' reminder, in *The Sociological Imagination* (1959: 3) that "The facts of contemporary history are also facts about the success and the failure of individual men and women," and that "Neither the life of an individual nor the history of a society can be understood without understanding both". Much progress has been made in linking self and society in aging research, especially by life course

theorists. However, to advance the field, North American social gerontologists will have to continue to struggle with the conceptualization of social structure. Moreover, this is not a challenge for theorists of aging only. Rather, it is probably the leading theoretical challenge for the social sciences in general.

Greater Dialogue with General Social Theory

In an insightful essay of 1988, the time when theorizing was moving beyond the early stage to what we are terming more recent work, Martin Kohli argued that while the sociology of aging has often borrowed from general sociology, it has rarely returned much to general sociology. This remains largely true today. He suggested that one major avenue to do that would be by theorizing what society will look like when smaller proportions of the population, at any one time, have their lives structured by work. With great fluctuations in age patterns of labor force participation since Kohli made this suggestion, it still remains an area in which aging theorists have much to contribute. This theorizing will probably draw heavily on the life course perspective, which aging research in the area of work has already helped to refine, but it will also draw on, and hopefully contribute to, the political economy perspective and to critical theory.

If theoretical development in social gerontology is to flourish, it will be due to the openness of social gerontologists to working with existing general social theory. For example, the notable social theorist Giddens (who is not, however, identified as a gerontologist) has theoretically articulated a view of trajectories of the self in the risk society of late modernity that may be helpful to social gerontologists in the life course perspective, particularly those who actively seek to link the micro and macro dimension from an interpretive perspective. As a second example, drawing on Foucault, Bourdieu, and other major sociological theorists who are definitely not gerontologists, Katz has developed a cogent historical sociology of how gerontological knowledge develops as a discipline while co-constituting the aged as a social group. As a third example, many social gerontologists have made creative use of exchange theory and related micro-economic theories that assume people make rational calculations and strive, in their social relationships, to maximize utility (the rewards minus the costs) of the actions. Ideally, greater openness of social gerontology to general social theory will result in an increased two-way flow of knowledge.

Theorizing Diversity

Another challenge for theorizing in social gerontology is to better grasp diversity. The call for this has taken different forms in the history of the field, from Neugarten's distinction between the 'young-old' and 'old-old,' to Dannefer's plea for a 'differential gerontology,' to the life course theorists' recognition of the principle of cumulative advantage. Additional theoretical gains may come from refinements in feminist theorizing.

We take the position that feminist theory is distinguished from sophisticated general social theory only by the commitment of the theorist to use theory in certain ways as a critique of mainstream gerontological research for its neglect of the gendered nature of work life, family life, and social stratification. Much feminist theorizing in social gerontology draws heavily on the political economy approach, and some such theorists label themselves as 'social feminists' or 'Marxist feminists.' McMullin (2000: 517) stresses the importance of placing gender analyses in a broader conceptual framework and suggests that feminist theory is superior to the age stratification and political economy perspectives: "… for a theory to be well suited for diversity research at least two criteria must be met. First, class, age, gender, and ethnicity/race must be conceptualized as power relations, and second, they must come together as an interlocking hierarchy of power rather than as separate systems." Feminist aging scholars such as Calasanti, McMullin, and Estes are contributing to a better understanding of the interplay of different aspects of diversity, of which gender is only one.

Facing these challenges will also call for a recognition that the aging experience of individuals and cohorts has to do with much more than the two domains that currently characterize the field of social gerontology: health and family. Aging does occur in the context of a life course, and life courses occur in the context of social structures that act as either opportunity structures or structures of constraint. At a structural level, life course and aging takes on global aspects in an increasingly interdependent world. To adequately understand individual processes of aging, scholars have to find a way to understand the dynamic relationships that link self and society. We anticipate that productive research will continue to occur at both the social psychological and the social structural levels, but the real payoff will come when theorists succeed in this linkage. Finally, research in the social aspects of aging too often leaves us asking, 'what does all this mean for the individuals involved?' The current structures of research funding and publication

favor normative rather than interpretive research, and it is no surprise that we have more research in the normative than in the interpretive tradition of the social sciences. We need both. Social theory in aging has yet to adequately address these issues.

See also: Life Course; Modernization and Aging; Politics of Aging.

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Thirst and Hydration

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Glossary

Anosmia – Absence of the sense of smell.

Dehydration – Excessive loss of body water, usually resulting from a negative balance between fluid intake and output.

Dipsogenic – Thirst provoking.

Dysgeusia – Distortion of the sense of taste.

Homeostasis – Tendency to maintain stability or constancy of the internal physiological environment.

Hypodipsia – Physiological condition resulting in delayed initiation of drinking.

Osmoreceptor – Central nervous system receptor that responds to changes in plasma osmotic pressure.

Thirst – A strong, uncomfortable desire or craving to drink liquid.

Introduction

Franz Grillparzer, a nineteenth-century Austrian classical dramatist and lyric poet, captured the essence of the impact of age-related hypodipsia in one of his writings: "Drink and be thankful to the host! What seems insignificant when you have it, is important when you need it." (Sauer A (ed.) *Complete works of Franz Grillparzer*, 5th edn. Stuttgart, 1892–93).

Table 1 Thirst regulation in older adults: Homeostatic and non-homeostatic factors

Homeostatic
Plasma hyperosmolarity
Hypovolemia
Plasma renin activity
Peripheral and central vasopressin levels
Oropharyngeal metering
Non-homeostatic
Hedonic qualities of fluid
Palatability of drink
Fluid preference
Availability
Sociocultural influences
Lifestyle habits
Social isolation
Functional status
Associated comorbidity

Thirst is perceived as an uncomfortable sensation that exerts a motivational effect on drinking behavior and resolves with fluid consumption. In humans, the perception of thirst is subject to a complex interplay between physiological homeostatic mechanisms and behavioral influences that trigger drinking under a variety of circumstances. Under stressful conditions, physiological thirst mechanisms are ultimately responsible for the maintenance of fluid balance. However, in the healthy adult, under non-stressful conditions, thirst and subsequent fluid consumption are modulated primarily by non-regulatory and behavioral factors. Thirst may therefore be classified as either homeostatic or non-homeostatic (**Table 1**).

Thirst and Homeostasis

Hyperosmolarity and hypovolemia are the two major pathophysiological mechanisms that influence thirst. Specialized osmoreceptor cells function as tonicity sensors responding to changes in plasma osmolality. Although the precise neuroanatomic site of these osmoreceptors is unknown, animal studies suggest a location in the hypothalamus within the organum vasculosum and the subfornical organ of the lamina terminalis. Afferent neural input arising from these osmoreceptors is conveyed within the nucleus tractus solitarius. The latter nucleus also contains fibers arising from peripheral baroreceptors located within the aortic arch, carotid sinus, and left atrium. Subsequently, fibers from the nucleus tractus solitarius converge on the supra-optic and paraventricular nuclei, from where axons travel via the median eminence to the postpituitary gland, thereby modulating vasopressin release. In addition, other fibers from the nucleus tractus solitarius converge on the lateral pre-optic area of the hypothalamus that is responsible for stimulation of the thirst sensation and drinking. Thus, plasma hypertonicity, and to a lesser extent, hypotension and volume depletion, increase vasopressin release and elicit a homeostatic dipsogenic response.

Maintenance of fluid homeostasis is also facilitated by modulation of the renin-angiotensin system. Intravascular volume depletion increases plasma renin levels and consequently elevates angiotensin and aldosterone levels. Subsequently, the potent dipsogenic effect of renin and angiotensin I and II encourages drinking. Intraventricular administration of angiotensin II also stimulates vasopressin release, in addition to stimulating thirst. Available evidence also indicates the presence of an independent central renin-angiotensin axis that may exert a central modulatory effect on thirst and vasopressin release.

Of mounting interest is an additional, though poorly understood, thirst regulatory mechanism described as oropharyngeal metering. Evidence suggests that the act of swallowing is the afferent limb of a conceptual pathway that regulates the volume of fluid ingested in response to dipsogenic stimuli. Although the exact pathophysiology is unclear, this pathway is thought to account for the rapid assuaging of thirst following drinking, even prior to the restoration of euvolemia and normal tonicity. Additionally, this regulatory mechanism may also be involved in the dampening of vasopressin secretion that occurs during drinking. It is likely that the teleological role of the oropharyngeal reflex is to bar the excessive ingestion of water.

Drinking is a voluntary and highly coordinated function indicating involvement of multiple complex neural pathways. However, neural pathways responsible for the cortical control of drinking and dipsogenesis remain poorly defined. This is likely due to the confounding effect of multiple psychosocial and behavioral influences on drinking habits.

Thirst and Aging: Homeostatic Regulation

Older adults are more likely to develop hyperosmolar dehydration following water deprivation. Reasons for the increased risk of dehydration in older adults include a reduction in total body water with aging and age-related impairment in renal tubular concentrating ability. Dipsogenic influences therefore assume increased significance in fluid homeostasis in older adults.

Age-related hypodipsia is well recognized. Additionally, compensatory dipsogenic fluid repletion, following a period of water deprivation, proceeds at a much slower rate in older adults. However, available

evidence indicates that fluid deficits are eventually fully replaced. Experimental data obtained from human studies of hypertonic saline infusion reveal comparatively lower levels of thirst and less water intake in older adults compared with younger adults. These findings support the theory of age-related blunting of osmoreceptor sensitivity. Hypertonic saline infusion in older adults results in increased vasopressin release, suggesting an age-related increase in the sensitivity of central vasopressin neuroreceptors. Thus, it is plausible that age-related attenuation of the thirst response is more likely due to altered circulating vasopressin levels. Indeed, there is a loss of circadian rhythm resulting in nocturnal peaking of vasopressin secretion in older adults. However, studies have yielded conflicting results regarding age-related changes in circulating baseline and diurnal vasopressin levels.

Several other hormones have been implicated in the etiology of age-related hypodipsia. Intravenous infusion of pharmacological levels of atrial natriuretic peptide has been shown to inhibit osmotically induced dipsogenesis and vasopressin secretion. Likewise, data relating the relatively higher levels of circulating norepinephrine (NE) levels to the known antidipsogenic effect of NE suggest a possible role for NE in the genesis of age-related hypodipsia.

Altered opioid sensitivity may play a causal role in age-related physiological hypodipsia. Administration of naloxone has been shown to suppress fluid intake after overnight water deprivation in younger subjects. However, the antidipsogenic effect of naloxone is far less pronounced in older adults, raising the possibility of reduced opioid receptor sensitivity with aging.

Available data from animal studies also suggest that aging results in an attenuated rise in plasma osmolality in response to thermal dehydration. Additional evidence also supports an age-related reduction in salt appetite responses to regulatory challenges. Animal studies comparing the response of young and older rats to captopril-adulterated drinking water show that young rats significantly increase daily ingestion of 0.3 M NaCl when provided as an alternative to water. In the absence of a saline drinking solution, young rats simply increase daily water intake. Older rats fail to exhibit a similar differential response when offered both saline drinking solution and water.

Age-related changes in oropharyngeal metering have not been described. Pharyngeal dysphagia, resulting from esophageal dysmotility, is a recognized complication of presbyesophagus. However, the effect of this condition on oropharyngeal metering as a fluid homeostatic mechanism requires exploration. Similarly, other age-related oropharyngeal responses are ill defined. Traditionally, taste and tactile sensations are considered the primary sensory modalities perceived by the oral and lingual surface. However, degrees of moistness are perceived within the oral cavity. It is plausible that persons with age-related dysgeusia might also exhibit an attenuated response to dryness of the oral mucosa. Further research is needed in this area.

Thirst and Aging: Nonhomeostatic Regulation

Much of the research on thirst focuses on homeostatic responses to fluid deprivation and altered plasma tonicity, possibly because fluid balance in the younger, healthy adult is notably threatened only under conditions that overtly disrupt homeostatic regulation. In contrast, older adults not only are subject to the effects of physiological attenuation of fluid homeostasis, but also face the threat of compromised non-homeostatic dipsogenic influences. Available evidence indicates that approximately 15% of adults over the age of 65 years and 25% over the age of 85 years drink insufficient amounts of fluid for a variety of inappropriate attitudinal reasons. The most prominent reasons identified for limiting fluid intake were lack of thirst and fluid restriction to combat urinary incontinence or nocturia.

The significance of non-homeostatic factors is highlighted by studies of ad lib fluid intake, which indicate that physiological regulation of fluid intake rarely comes into play in free-living healthy individuals, regardless of age. When fluid is available, data indicate that in both young and old adults, thirst results in fluid intake well before hypovolemic or hypertonic deficits occur. Dipsogenic triggering events are undoubtedly complex and intricate. Multiple non-homeostatic dipsogenic factors include hedonic influences such as appearance, ambience, fluid preferences, and palatability. Thus, age-related sensory impairments such as dysgeusia, anosmia, and impaired vision might detract notably from the hedonic qualities of fluids. Psychological influences, sociocultural expectations, health awareness, and lifestyle habits also affect the type and quantity of fluid consumed. Most importantly, data indicate a positive correlation between food intake and fluid intake, introducing age-related and pathological anorexia as additional factors in threatening fluid balance in older adults. Increased isolation and impaired functional status may further restrict access to fluid. Acute illness and chronic disease have a notable, albeit variable, effect on fluid balance in older adults. An added variable that threatens fluid balance is

the effect of medication and polypharmacy on fluid balance.

Dehydration in the Elderly: Clinical Overview

Dehydration is highly prevalent among older adults, occurring in more than one million elders admitted to acute care facilities each year in the United States. Annually, health-care expenditure on dehydration among persons older than 65 years exceeds 1.2 billion dollars. Complications of dehydration are myriad, including delirium, falls, and incontinence (**Table 2**). Associated mortality rates approach 50%. Multiple clinical factors predispose the older adult to dehydration. Although an exhaustive review of the clinical causes, diagnosis, and treatment of dehydration is beyond the scope of this article, it is pertinent to note that most of the causes of dehydration are avoidable and easily reversible. Prompt clinical detection, however, depends on increased awareness of the risk of dehydration in geriatric patients. Reliance on clinical diagnosis of dehydration is confounded by the poor predictive value of traditional clinical indices of dehydration. Poor skin turgor and lack of axillary sweating correlate poorly with dehydration in older persons. Similarly, dry oral mucous membranes are insensitive signs of dehydration in older patients, as adverse effects of medication and mouth breathing may produce identical changes. Furthermore, available data show that orthostatic hypotension in older patients does not reflect dehydration severity, as medications, age-related changes, and prolonged bed rest may also result in orthostasis via autonomic dysfunction. So far, selected laboratory indices of dehydration, namely, serum osmolarity >300, blood urea nitrogen >20, or BUN:creatinine ratio >20, are the most reliable indices of dehydration.

Table 2 Complications of dehydration in the elderly

Cardiopulmonary
Fatigue
Reduced exercise tolerance
Hypotension
Gastrointestinal
Constipation
Dysgeusia
Anorexia
Dental caries
Weight loss
Neuromuscular
Delirium
Cognitive impairment
Thrombotic cerebrovascular disease
Falls
Dermatological
Pressure ulcers
Recurrent skin infections
Renal
Hypernatremia
Nephrolithiasis
Urinary incontinence
Dysuria
Renal failure
Increased risk of uro-epithelial malignancies

Ultimately, prevention of dehydration is the most cost-effective method of thwarting this potentially fatal, yet easily treatable, condition. Dietary guidelines for older Americans recommend consumption of at least 2 liters of fluid daily. However, there is limited evidence to support this arbitrary figure. Available evidence-based data support the benefits of ingestion of at least 1.5 liters of fluid daily. Currently, it is unclear as to whether regular consumption of fluids in excess of this amount may result in dilutional hyponatremia and other consequences of water overload. Treatment of dehydration mandates due attention to restoration of normal plasma tonicity and correction of the fluid deficit. Older persons who are unable to ingest fluids orally may require parenteral fluid administration. Intravenous administration is the traditional method. However, health professionals should be aware of the utility of alternative routes, such as percutaneous gastrostomy, that may be preferred in older adults with co-existing anorexia or dysphagia. Subcutaneous fluid infusion (hypodermoclysis) is a convenient, simple, relatively safe, and cost-effective method that is particularly effective in older patients in subacute or long-term care.

Effective management of dehydration in the older adult mandates meticulous attention to pathophysiological stressors in the context of pre-existing hypodipsia. Ultimately, the ideal therapeutic goal is the development of an individualized fluid maintenance and hydration intervention strategy for all older adults, healthy or otherwise.

See also: Dementia; Endocrine Function and Dysfunction; Homeostasis, Homeodynamics and Aging; Neurotransmitters and Neurotrophic Factors; Renal and Urinary Tract Function.

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Time: Perceptions and Concepts

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Glossary

Biological Clock – Generic term for biological processes that show periodic behavior and are clock-like in their rhythmicity.

Biological Time – A species-dependent unit of physical time required to complete a species-independent biological event or process.

Physical Time – Generic term for solar, calendar, clock, objective, historical, dialectical, and social time.

Social Clock – Metaphor for the timing of social events and age-appropriate behavior.

Time Confound – Interdependency of seemingly independent time parameters.

Time Perception – Generic term for the experience of time, subjective judgment, and/or the amount of elapsed time.

Time Perspective – The totality of the individual's views of his or her psychological future and his or her psychological past existing at a given time.

Introduction

Time is a symbol for a connection made by a group of beings with the capacity for memory and synthesis between two or more continua of changes, one of which is used by them as a frame of reference or standard for measuring the other or others. Relations of time are therefore connections between at least three continua: between people who bring about connections and two continua of changes, to one of which they give the function of standard continuum, a frame of reference for the other. In modern society, physical time – also called solar, calendar, or clock time – plays the role of standard continuum, a frame of reference for the other continua of changes such as biological, psychological, and intrinsic time. In this context, social time is conceived as a tautology for physical time. In this article, distinctions between major concepts of time are presented, as well as their corresponding clocks and age scales, to begin with physical time in relation to calendar (days, months, years), clock (hours, minutes, seconds), and chronological age.

Physical Time

History

In Western antiquity, time was conceived in two ways, as a cycle and as a line. *Cyclic* time is the oldest concept, as the image of the cycle best applies to natural phenomena like the revolution of the planets,

the succession of the seasons, night and day, sleeping and waking, growth and decay. *Linear* time, however, is not a product of observables; it is an abstraction, developed successively by the Greek philosophers Pythagoras (the nature of things is number), Plato (time equals the number of revolutions of the planets), and his pupil Aristotle (384–322 BC), who defined times as "number of motion in respect of before and after." In brief, the classical concept of time is an aspect of motion that makes possible the enumeration of successive states linearly by dividing up cycles (of planets) into units. This concept lasted in science for almost 20 centuries, when, at the end of the seventeenth century, it was displaced by physicist Sir Isaac Newton (1642–1727).

Newton conceived of time as something *absolute*, an immaterial, fixed property of the universe by which motion or change can be measured. Thus, in classical physics, time is an absolute standard or measuring scale. In this view, time is not only *linear*, but also *reversible*, for nothing changes when t is replaced by $-t$ in physical equations. Because the Newtonian concept of time is not a product of the perceiving subject, absolute time is often called objective time. This concept has become equated more and more with its measure, the mechanical clock. Consequently, time has become transformed and reified into *objective*, *mechanical*, *calendar*, or *clock* time. Objective time is basic to seemingly different time variables, such as period or historical time, chronological or calendar age, cohort or time of birth, calendar time, and clock time. They all can be reduced to the same, basic concept of classical-physical time.

Concept of Physical Time

Newton's physical time does not have intrinsic direction; there is no difference between its past orientation $(t-)$ and its future orientation $(t+)$. This concept of time violates generally accepted natural laws. Natural phenomena are described by the second law of thermodynamics, which states that chaos or disorder will increase irreversibly with energetic processes. Thus, the direction of physical time is defined by the irreversible destruction of macroscopic order, or the increase of *entropy*. In twentieth-century physics, time is no longer reversible but irreversible, at least at the macroscopic level.

It should be noted that the modern concept of *physical* time as *linear* and *irreversible* did not change the conception of chronological age as additive, that is, a quantity that can be added, subtracted, multiplied, and divided regardless of the age of the organism. The implication is that all possible calendar ages of the organism are equal. For instance, the first 20 years of life are equal to the middle or last 20 years of life. This, however, makes sense only from a purely clock or calendar time perspective.

Biological Time

Biological Clocks

Many biological processes show periodic behavior and are clocklike in their rhythmicity, in particular biological processes on a 24-h basis, the so-called *circadian* rhythms. These rhythms, as well as the progressive reification of time in terms of mechanical clocks, encouraged the search for biological instead of mechanical clocks. The major anatomical clock for numerous physiological (blood pressure, hormones, body temperature) and behavioral (attention, reaction time) processes with circadian variation has been located in the *suprachiasmatic nucleus* at the base of the brain. The circadian rhythm of this clock differs slightly from the earth's rotation cycle of 24 h, and from one individual to another (e.g., 24.5 or 25.5 h periods instead of 24 h). Because the internal period deviates somewhat from 24 h, it has to be reset daily to retain synchrony with the external light–dark cycle. This process is called *entrainment* or synchronization. In brief, daily synchronization is reached under the external influence of physical and social timers like the light–dark cycle and the well-structured 8-h working day.

Another major class of so-called *metabolic* clocks is based on *energy transformations* or metabolically related processes and functions in the organism, Metabolic clocks are inferred from the rhythmic activity of, for example, heart, lungs, and intestines, on the basis of the allometric power law $M^{0.25}$. This law says that the length of time between consecutive heart beats increases as a linear function of about the 0.25 power of body mass (M) in mammals. The *basal metabolic rate* (BMR), or the time needed to process one joule per gram, also increases with $M^{0.25}$. Corrected for weight, all mammals use an equivalent amount of joules per heart beat, per generation, or per life span. This suggests that metabolic clocks, as time measures of numerous periodic phenomena in the human organism, are closely associated with the rate of living. Also, positive or negative events influence biological-periodic phenomena, modulate metabolic clock rate, and thereby increase or decrease the *rate of living* within limits.

Using the clock metaphor, the human organism can be viewed as a clock shop with two master clocks – circadian and metabolic clocks – and many entrained

slave clocks. Aging of the organism may involve *desynchronization* of the clock shop, in which the various master and slave clocks that are normally in synchrony are put out of phase; amplitude and period may be changed as well. There is more and more evidence for a strong relationship between the temporal organization of organisms with age and the occurrence of mortality and morbidity patterns (sleeping disorder, reduced thermoregulatory capacity, depression, and Alzheimer's disease). As such, measures of the degree of synchronization in the elderly might function as predictors of nearness of death.

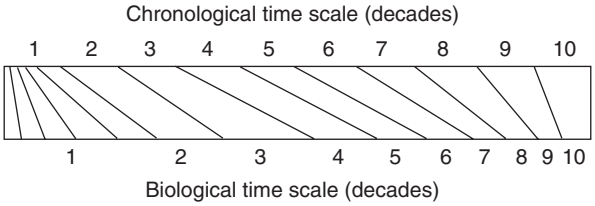

Figure 1 Schematic comparison of chronological and biological time scales. Much more biological activity (e.g., metabolic activity) can be packed into the first decades of biological time than into those of later life; hence the length of that part of the biological measuring rod appears to be longer in the early period of life than a comparable portion of the chronological measuring rod. At the other extreme of life the opposite relationship applies.

Concept of Biological Time

The individual human life might be viewed as governed by a single biological clock or individual life cycle with one period. The length of this period, that is, *length of life* or life span, reflects the rate of biological aging and is one of the most significant characteristics of biological time. Length of life as a variable, however, raises two serious problems. First, it is virtually impossible to construct a time scale for the measurement of biological time on the basis of a single clock with one period. To solve this problem, biologists have looked for an alternative length-of-life variable at the population level and have focused on the *probability of dying*. Second, biological time must be defined with reference to a specified biological process. The probability of dying is not a biological process but a statistical concept, and the length-of-life variable reflects at most an undetermined biological process.

Given the foregoing, biological time can be defined as a species-dependent unit of physical time required to complete a species-independent biological event or process. In other words, a biological time scale for a specified biological process can be constructed by transforming a chronological time scale so that the rate of change of the process becomes time invariant in biological time. Recently, several physiologists have pointed out that the metabolism of the organism over the life span might be that biological process. It should be noted that *biological* time is not only *irreversible*, but also *non-linearly* related to physical (objective) time or chronological (calendar, clock) time. **Figure 1** shows how chronological and biological time scales might be related.

Psychological Time

Time Perception

On a clock in Chester cathedral (UK) the following inscription can be read "For when I was a babe and wept and slept, Time crept/When I was a boy and laughed and talked, Time walked/Then when the years saw me a man, Time ran/But as I older grew, Time flew." Put in this verse is the phenomenological view that time passes faster with age. This view refers to the perception, awareness and/or the experience of (the passage of) time. *Time perception* is used here as the generic term for the experience of time, subjective judgment and/or estimation of the duration of events or the amount of elapsed time. Since the publication of Paul Janet's study in 1877, several studies have sought to quantify the acceleration of time as a function of chronological age. Broadly speaking, three approaches can be distinguished.

First, classical psychophysical studies based on the metaphor of *temporal modality*. This metaphor implies a sensory receptor system for time, so that Weber's law (we perceive not the difference between sensations, but the ratio of this difference to the magnitude of the sensations compared) can be put to the test for differences in duration between various time intervals. It has been suggested that subjective duration varies inversely with the square root of chronological age, but too many exceptions to the rule have been found in practice. In the final analysis, the psychophysical approach did not prove to be very productive.

Second, by analogy with biological clocks an *internal psychological clock* has been hypothesized. The slowing of this clock can occur with advanced age, decreased metabolic activity, lower body temperature, and use of alcohol, barbiturates, and other drugs. External clock time by comparison seems to be going faster – time seems to fly like magic – and clock time will be underestimated. The reverse also holds: when a person's internal clock is going fast, then clock time by comparison seems to be going slow. This occurs when metabolic rate is increased, with higher body temperature (e.g., fever), and by the use of stimulants such as caffeine and psychedelic drugs. In general, the greater frequency of internal

changes per unit of clock time makes clock time seem to be longer (and the other way around). The internal clock metaphor also explains to some degree why the days seem to pass slowly for children, but rush past faster and faster with increasing age: children have a slightly higher metabolic rare, and consequently a higher body temperature than the elderly.

Third, Ornstein introduced in 1969 the *temporal information-processing* approach in cognitive psychology, which relates the faster passage of time to the fact that with advancing age there are less novel events in life worthy of being stored in memory. For children, everything is new, whereas old age brings fewer surprises. The cognitive approach of time perception is a highly specialized area: models of time estimation are formulated in terms of event-related attributes rather than in terms of clocks, and the models used are only fit for the perception of brief durations in the 100 ms to 10 s range.

Summarizing part of the results of both long-term and short-term memory research on the subjective experience of time, it might be said that unpleasant emotions are associated with a feeling of time urgency, making (external) clock time by comparison seem to pass slowly. During pleasant emotions, however, there is less time urgency and, therefore, clock time by comparison appears to go quickly.

Time Perspective

According to St. Augustine's *Confessions* (ca. 400) there are three times: a present of past things, a present of present things, and a present of future things. Together they form the basic elements of what has been called *time perspective*, which Kurt Lewin defined as the totality of the individual's views of his psychological future and his psychological past existing at a given time; in other words, the individual span of awareness extending into the past or future. This raises the question of the subjective duration of the present.

According to William James (1890), the *mental now*, classically known as the specious present, has a certain duration: It is no knife edge, but a saddle, with a certain breadth of its own on which one sits perched, and from which one looks in two directions into time. Some authors report 20–200 ms as minimum duration of the mental now, whereas others mention 4–7 s; the latter figures are more consistent with modern research data. Another characteristic of the individual present is its temporal *intentionality*; that is, the mental now is directed at the past, the private world of memories, as well as the future, with its individual expectations. How the past, present, and future temporal realms interrelate with one another can be stated as follows: both past and future are hypothetical reconstructions interpreted from and bound together through the mental now. In other words, the psychological past and future are *constructions*, experienced as a series of presents.

In research on time perspective several dimensions of significance can be identified. The basic dimension of *time orientation* refers to the relative dominance of the past, present, and future in an individual's thinking. Most often dealt with is the dimension of *extension*, which is based on reported life events and their estimated ages of occurrence, which can be defined as the length of past, present, future, or total life time considered by the individual. In this context, the question arises whether the individual's future extension diminishes with advancing age. The answer on the basis of research evidence is that advancing age does not necessarily lead to a loss of futurity. The empirical studies of time perspective instead point to increasing individual differences with age as well as an increasing complexity of the individual's time perspective.

Finally, most research on time perspective is based on explicit reports or implicit expectations of (1) life events, and (2) their estimated ages of occurrence. This type of operationalization is notorious for methodological problems with the analysis, coding, and interpretation of the data, with the result that the outcomes of time perspective studies are difficult to replicate.

Concept of Psychological Time

Time perception and time perspective might be conceived as the two basic dimensions of psychological time, crossing each other in the mental now of the individual's temporal awareness, However, the concept of psychological time is extremely complex and embraces more than the temporal dimensions of perception and perspective. For example, *psychological time* might be simply defined – by analogy with biological time – as the unit of chronological time required to complete a psychological event. Next, this simple definition might be extended with the following characteristics or aspects: (1) psychological time may pass in a non-linear fashion; (2) its flow may be perturbed by either internal or external influences; (3) it may become detached from the past, affirming persistence within the present; and (4) it may function in a manner unrelated to causality. To cut a long story short, a definition of psychological time can be given only in terms of temporal dimensions, characteristics, and/or aspects.

In the final analysis, however, the following conception of a psychological time scale comes closest to

the ideal definition of psychological time, i.e., in which each psychological event has its own unique place on the absolute time scale of personal history and future, which defines a conscious present, a privileged now, but also beginnings and endings.

Social Time

Concept of Social Time

Concepts of physical, biological, and psychological time refer to corresponding time scales with specific features. It is difficult, perhaps even impossible, to delineate the features of a social time scale, which is identifiable with the concept of social time. Definitions, or even cues for possible definitions of social time, are not presented in the social sciences. At best, *social time* might be defined as the unit of chronological time required to complete a social event.

It should be noted that the term social time is used very frequently, but also improperly in social science. What sociologists and other social scientists mean, if they refer to social time, is not essentially different from the calendar or clock time of social phenomena. In other words, the term social time, as well as the related term *dialectical time*, is simply another disguise of the basic concept of physical time.

Social Clocks

In the social sciences, various age-related concepts have been introduced. Anthropologists were the first to introduce the concept of *age grading*. Age-graded systems are expressions of the fact that all societies divide time into socially relevant units, thus supposedly transforming calendar time into social time, although clustering rather than transforming calendar time into (chronological) age grades would be more to the point of the physical time scale used.

Another age-related concept is *age stratification*, i.e., chronological age strata function as an organizing principle in society. Because age-related roles may change under the influence of history-normative events, society will change as new birth cohorts replace older ones. The concept of age stratification emphasizes that there are significant variations in older people depending on the characteristics of their birth cohort. A second important feature of age stratification is the emphasis on the relations of cohorts within the age structure of society; this makes possible the analytical distinction between developmental age changes and cohort historical differences.

Age grading and age stratification lie at the root of the idea that every society has a system of social *expectations for age-appropriate behavior*, and that all members of that society internalize these expectations or so-called age norms as they grow up and move from one age stratum to the next. In brief, age norms constitute a script, timetable, calendar, or time schedule for the life course, and function therefore as social controls. In this context, social gerontologist Bernice Neugarten found widespread consensus regarding the timing of events, that is, the appropriate age when individuals are expected to go to school, to marry, to start a career, and so on. People know whether they are 'on time' or 'off time' as if they have a *social clock*; furthermore, they feel good about themselves when they are on time, but they feel bad if they have been either early or late.

The lack of fit between the individual timing of events and social clocks is called desynchronization. In general, the greater the degree of individual temporal desynchronization, the greater will be the sense of stress. Recently, a *social entrainment model* has been developed, which emphasizes that various temporal rhythms underlie a wide range of social behavior and that synchronizations among them (or the lack of such synchronizations) have widespread and crucial implications for human cognition, social interaction, task performance, and role behavior, and therefore for human health and well-being. The basis for the model lies in the notion of *entrainment* as introduced in the section on biological clocks. Viewed from a social perspective, entraining cycles correspond with Neugarten's social clocks or prescriptive timetables, for example, but they may also refer to conversational behavior, group interaction, or task performance. Summarizing, the social entrainment model provides a framework for describing the operation of biological, psychological, and social clocks, their coupling to one another and potentially to outside pacers (signals), and the temporal patterns of behavior resulting from these clocks and rhythms of human behavior.

Time Confounds

The concepts of age grading, age norms, age strata, social clocks, and social time are all aspects of the same time scale, calendar time, or physical time, of which chronological age (or calendar age) is still the most popular, though much abused, index. Chronological age is usually introduced in developmental and aging research as an *independent* or *explanatory variable*. However, chronological age does not have much explanatory power by itself, which is not surprising after all, as both independent and dependent variables are expressed in terms of the same calendar time, the source of most time confounds. Precisely because of the problem of confounded time parameters, K. Warner Schaie proposed in 1965 a

general developmental model with three interdependent, objective time parameters. This so-called *APC model* is based on the formula that age = period (or time-of-measurement) – cohort (birth), and has served to separate statistically age, period, and cohort effects. However, regardless of how data are collected, there is a triple confound. In later studies, it has been noted that the triangular confound is not unique to developmental or aging research, but even more important is the observation that a strictly statistical solution to the APC problem, or any other triangular confound for that matter, is not possible.

A radical solution to the problem of time confounds is to get rid of time itself by redefining its meaning. In research practice, psychological and social phenomena are inferred from the calendar or clock. By identifying the meaning attributed to various time parameters, it should be possible to unlock some of the confounds. Schaie made an attempt to solve the APC problem by conceptually separating historical time (time of measurement or period) and cohort effects from calendar time. Essentially, he redefined cohort as a selection variable that characterizes the common point of entry for a group of individuals into a given environment. Period, on the other hand, is translated into a measure of event density, Thus, Schaie was able to remove calendar age as a confound for cohort or period.

Intrinsic Time

Age Scales

James E. Birren has repeatedly observed that chronological age or the elapsed physical time in days, months, and years since birth is one of the most useful single items of information about an individual if not the most useful. Nevertheless, the useful, though rough index of *chronological age* is not very sensitive to individual differences. For that reason, Birren introduced three new age scales and contrasted them to chronological age. The first scale, *biological age*, can be defined as an estimate of the individual's present position with respect to his or her potential life span. Such a measure of biological age should be able to predict the residual life span of the individual with a smaller error than that based on chronological age alone. The second scale, *psychological age*, refers to the age-related adaptive capacities of the individual, such as perception, learning, and memory. Just as one may be older or younger than one's chronological age in a biological sense, one may also be older or younger psychologically. Presumably, a measure of psychological age would correlate highly with chronological age and also with environment. The third scale, *social age*, refers to acquired social habits and status, to the individual's filling the many social roles or expectancies of a person of his or her age in his or her culture and social group. An individual may be older or younger depending on the extent to which he or she shows the age-graded behavior expected by a particular society or culture. A measure of social age presumably would also be related to chronological age, somewhat to psychological age, and to a lesser degree to biological age.

Due to its popularity in industrial organizations, as well as its close affinity to biological, psychological, and social age scales, the functional age scale needs to be explained. *Functional age* can be defined as a dimension in which individuals could be younger or older than their chronological years in their ability to adapt to their environments. The individual's level of capacities for daily life functioning in society could be compared to other individuals of the same age by a series of measurements comprising operationalizations of biological, psychological, and social ages, respectively. Functional age scales have been severely critiqued for several reasons. First, there are different meanings of the terms *function* or *functional*, as they refer to occupational functional age, biomedical functional age, or to the structural organization of human functioning. Second, functional age researchers vary to the extent that they hypothesize a unitary aging process on the one hand, or prefer to assume multiple aging processes and various combinations of variables, each of which may be optimally employed for different situations or against different criteria. Third, two criteria have been put forward: chronological age and length of life (residual life span). The most common approach is to employ multiple-regression techniques to predict chronological age or length of life. If the ultimate criterion is chronological age, then the functional age measure does not make much sense, as chronological age can be assessed much easier (just ask for it). The second criterion, length of life, residual life span, or the person's time until death is more promising, although no conclusive studies have been conducted yet. For the time being, chronological age is the best general index to the residual life span of healthy individuals.

Concept of Intrinsic Time

In the foregoing discussion, various concepts of time and age were introduced from a physical, biological, psychological, and social perspective. The question arises whether these different concepts can be integrated in a general concept of time and age, valid for all (levels of) living systems. A tentative

answer has been given by theoretical biologist Robert Rosen, who assumed that any given dynamics of any system will generate its own intrinsic time; that is, *intrinsic time* is created by physical, biological, psychological, or social processes as an emergent property of their *non-linear dynamics* (energy transformations). In plain words, *intrinsic time* depends on the number of transformations or changes, intrinsic to the dynamics of the system. As such, intrinsic time is a *dependent variable*.

From the above it follows that intrinsic time is scaled by the system from which it emerges. As any dynamic process can serve as a clock, intrinsic time is measured by monitoring one of the state variables undergoing change. The dimensional unit of this intrinsic time is simply the unit of the state variable chosen for observation. For example, consider the primitive clock made by notching a candle at 1-inch intervals along its length. With a fresh candle as the initial condition, time is given as the length L of candle burned. The unit of time intrinsic to this particular dynamical system is inches. Mathematically this is expressed by $t = L$, where t is intrinsic time. This time is well defined and will serve for many purposes. However, it is particular and intrinsic – and thus is absolute. A metric is needed to calculate the relative relationship of the intrinsic times of two candles having different constitutive parameters. Such comparisons are made by the promotion of one time-keeping device to the status of the standard clock with clock time t.

Rosen has developed an *entropic time metric*, based on the second law of thermodynamics, which states that there is an increase of entropy in energetic systems (entropy is defined here as the degree to which relationships between the components of any system are mixed up, undifferentiated, or random). The entropic time metric scales the passage of intrinsic time to standard clock time. Given this metric, the *intrinsic age* of any system might be assessed. Intrinsic age as an intrinsic, directed measure of the state of a particular system should be distinguished from chronological age, which is extrinsic, universal, and reversible. For instance, two systems are in temporal corresponding states, that is, at the same intrinsic age, at equal instants of intrinsic time. However, although they are at the same intrinsic age, they may have traversed different periods of extrinsic clock time and are, then, of different chronological age.

Intrinsic Age Scales

Generally speaking, the transformation rules between intrinsic time and other times (biological, psychological, and social) are not known. However, in biological systems the entropic time metric is probably associated with the metabolism of the organism, which relates to entropy production. Given the known relationship between total rate of change of entropy or metabolic rate of an individual and his or her chronological age, it is feasible to define a metabolic or *intrinsic biological age* scale for human subjects. The definition of an intrinsic age scale at the psychological system level is less obvious, but nevertheless feasible. To start with, all psychological events should be formulated in entropic terms. Normally speaking, psychological events are formulated in informational terms. Given however the concept of *negentropy*, which is a measure of negative entropy or information, it should be possible to compute the *intrinsic psychological age* of individuals by feeding the external entropy flow rate, as calculated from informational data, into the entropy equation for living systems. Similarly, the *intrinsic social age* of social systems might be computed, based on Bailey's social entropy theory. By means of these three *intrinsic age* scales, it should no longer be difficult to develop an *intrinsic functional age* scale for human individuals, which is a better predictor of length of life than chronological age, and replaces chronological age as an independent and dependent variable.

See also: Memory.

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Touch and Proprioception

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Glossary

Cutaneous – Term used in reference to receptors and stimulation that produce sensations of touch or pressure.

Glabrous Skin – Hairless skin found on the palms of the hands and the soles of the feet.

Kinesthesia – Term used to describe sense of movement of limbs.

Mechanoreceptor – Cutaneous receptor that mediates aspects of touch or pressure sensations.

Nociceptor – Cutaneous receptor that mediates pain sensitivity.

Proprioception – Term used to describe sense of the position of limbs in space.

Somatosensory – Term used to describe the receptors, afferent pathways, and cortical areas devoted to the senses of touch, temperature, and pain.

Thermoreceptor – Cutaneous receptor that mediates temperature sensitivity.

Introduction

The sense of **touch** is the encompassing term for a complex variety of sensations, including pressure, arising from mechanical deformation of the skin surface; temperature, arising from thermal stimulation of the skin; and pain, arising from potentially damaging application of mechanical, thermal, chemical, or electrical stimulation. Considered by many researchers as a separate sense is **proprioception**, the awareness of the position and movement of body and limbs in space. Both of these senses are mediated by a number of physiological receptive structures and central pathways, and both can be influenced by inputs from other sensory modalities, such as the visual and vestibular systems. And, like other sensory systems, the senses of touch and proprioception are vulnerable to the effects of aging. This article summarizes the state of knowledge in the psychophysics and physiology of touch and proprioception, together with research on how these senses change in aging individuals.

Touch

Physiology

The skin surface constitutes the largest sensory organ in the body, with a surface area of some 1.7 m^2 in the adult. The skin actually consists of numerous layers of tissue, which can be divided into two main sections, the epidermis, or outer layer, and the dermis, or inner layer. On the body surface are three kinds of skin: hairy skin, characterized by the presence of hair; glabrous skin, a hairless surface found on the palm and sole; and mucocutaneous skin, found at the entrance to various body cavities at the junction with mucous membrane. Although these skin types differ in the density and distribution of sensory receptors they contain, there are some general features that characterize most areas.

There are a number of structures believed to serve as receptors for transducing tactile stimulation. Variations in the density and distribution of receptors at different body sites influence responsiveness to a stimulus. For sensations of touch, pressure, and vibration, four different structures have been investigated as putative mechanoreceptors. These include the Pacinian corpuscle (PC), Meissner corpuscle (MEI), Merkel disk (MRK), and Ruffini cylinder (RU), all shown in **Figure 1**. It should be noted that in many cases the structure of these receptors makes it difficult to record activity directly at the receptor; instead, the probable role of a mechanoreceptive structure is

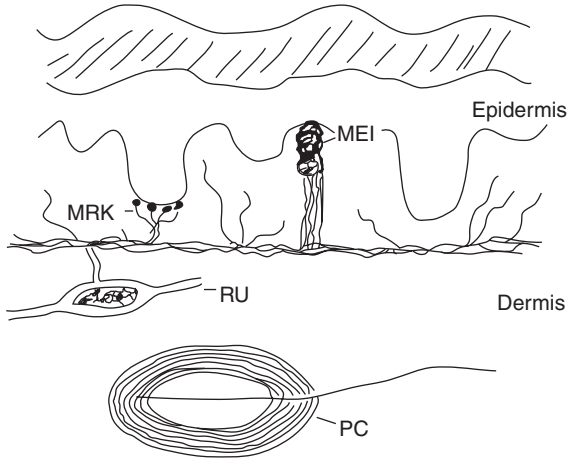

Figure 1 Schematic drawings of four mechanoreceptors. Shown are the Pacinian corpuscle (PC), Meissner corpuscle (MEI), Merkel disk (MRK), and Ruffini cylinder (RU).

inferred from activity measured in primary afferent fibers innervating the structure. Recent studies have addressed the relationship between end receptor and primary afferent response via microneurography, a technique in which activity is recorded by percutaneous microelectrodes from primary afferent fibers in awake human subjects, who can report sensations based on stimuli delivered to the skin at the same time as afferent activity is measured. This technique permits some confidence in assigning mechanoreceptive roles to particular cutaneous end organs.

The primary afferent responses measured for mechanical indentation are of two types: (1) slowly adapting (SA), indicating a response at stimulus onset that continues for the duration of the stimulation; and (2) rapidly adapting (RA), indicating a vigorous onset response, and perhaps an offset response, but no sustained response to a prolonged stimulus. Each of these two types of afferent response can be subdivided, based on the size of the receptive field (skin surface area) that excites a particular afferent fiber. Thus, afferent responses fall into four categories: SA types I and II, and RA types I and II.

The relationship between afferent response and end organ is best understood for the PC. The PC is a relatively large receptor, which in the adult has numerous layers (lamellae) that produce an onion-like appearance. PCs are located rather deep in the dermis, as well as in joints. Each PC is innervated by a single afferent, and thus it is straightforward to assume that transduction for a fiber takes place at the PC at the fiber's termination. Based on this relationship, it has been determined that the PC is RA and has a large receptive field. The distribution and placement of MEI, located at the junction of epidermis and dermis in the dermal papillae, suggests that they serve as the other RA mechanoreceptor. MEI are surrounded by an elastic capsule that is attached to the epidermis above and to the dermis below, and are supplied by 2–6 afferent fibers. Receptive field size for the MEI is small, particularly in comparison to the large field of the PC. Identification of the mechanoreceptors for the two SA fiber types is even more tentative. However, likely candidates for these endings are the MRK for the small receptive-field SA I fibers, and the RU for the larger receptive field SA II fibers. The MRK is a disk-shaped terminal located on certain basal epidermal cells, and the RU is a spindle-shaped capsule-like structure found in the upper layers of the dermis, although in many cases it is considered too loosely organized to reflect true encapsulation. Although these pairings are presently rather speculative, advances in microrecording techniques should permit more certain identification in the future.

The situation for thermoreceptors is even less certain than that for mechanoreceptors. A variety of receptive structures at various levels in the skin show a response to thermal stimulation; however, many of these also respond to other kinds of stimulation, such as mechanical. For example, the response of the PC is quite affected by changes in skin temperature, but the PC is thought to be primarily mechanoreceptive in function, rather than thermoreceptive. Some researchers have suggested a role for the Krause end bulb, but others have been less willing to speculate about the identity of individual thermoreceptors. As for the mechanoreceptors, the main source of information about the system has been the response profiles of individual primary afferent fibers, which appear to change their firing rates in response to either temperature increases or temperature decreases, but not both. Thus, one can speak of cold fibers and warm fibers. Some mechanoreceptors, as mentioned, modulate their response behavior in the face of temperature changes, but are not primarily considered to be thermoreceptors.

For sensations of pain, there appear to be several classes of receptors responding to excessive heat, excessive cold, or extreme mechanical deformation. Some also respond in the presence of chemical irritation. The fibers delivering information about noxious stimulation appear to terminate in free nerve endings scattered throughout the epidermis and dermis. A common feature of the pain receptors, or nociceptors, is their high thresholds for stimulation. In the case of pressure, the threshold for a pain receptor may be as much as 1000 times the displacement needed to detect pressure for a low-threshold mechanoreceptor. Similarly, thermal nociceptors may have thresholds of 45°C or higher for heat, or 15°C or lower for cold. Overall, it appears that the stimulus for these nociceptors must be intense enough to cause actual or potential damage to skin tissues (*see* Pain and Presbyalgos).

All of these receptors, whether mechanical, thermal, or pain, pass information via primary afferent fibers from the periphery to more central structures via the spinal cord. Cell bodies for these afferents are located in the dorsal root ganglia. Within the spinal cord, a functional division of fibers takes place, with larger-diameter fibers (carrying mainly mechanoreceptive information) forming the lemniscal bundle, and smaller-diameter fibers (carrying mainly thermoreceptive and nocioceptive information) forming the spinothalamic bundle. The lemniscal fibers ascend to the medulla, where they cross to the contralateral side before continuing on to the ventral posterolateral nucleus of the thalamus. Projection from the thalamus terminates in the somatosensory

cortex, located in the parietal lobe of the brain on the postcentral gyrus. Representation of different areas of the body in somatosensory cortex is somatotropic, that is, different parts of cortex are devoted to inputs from particular areas of the body. It is important to note that sensations of touch or pressure are mediated by cortical areas on the side of the brain opposite to the side of the body on which they occur, in contrast to projections from the visual and auditory systems, which are both ipsilateral and contralateral. In the spinothalamic pathway, neurons actually cross contralaterally while still in the spinal cord, synapsing in the dorsal horn, and ascend to the ventrobasal portions of the thalamus, from which they project to somatosensory cortex. The cortex itself is organized into two general areas, SI and SII, both of which may contain complete representations of all body areas.

Psychophysics

In characterizing the response of the tactile system to input stimuli, it is important to understand the impact of changes in various parameters of the physical stimulus, specifically, changes in spatial, intensive, and temporal aspects. In this section research into these stimulus aspects is summarized.

Spatial sensitivity in touch has been studied rather extensively, primarily using techniques such as two-point discrimination (in which the observer determines whether one or two points have touched the skin, at different point separations) and error of localization (in which the observer indicates the place where the skin was touched). More recently, tactile acuity for grating stimuli with varying separations impressed onto the skin has been measured. These measurements indicate that spatial acuity for tactile stimuli varies substantially across body sites. Areas such as the fingertips, tongue, and lips show excellent spatial sensitivity, whereas areas such as the abdomen and back are far less acute. At the fingertip, stimuli separated by as little as 0.5 mm can be discriminated, whereas on the abdomen, resolution is closer to 40 mm. Recent research has pointed to the MRK as the primary receptor for spatial sensitivity, based on its distribution across body sites. The MRK is most numerous at sites having the greatest spatial acuity. A secondary role in spatial sensitivity may be played by the MEI, which is also relatively dense in highly sensitive areas. Both of these receptors evidence small receptive fields, making them good candidates for spatial acuity mediation.

For the slowly adapting mechanoreceptive channels, SA I and SA II, punctate indentation is an adequate stimulus for excitation. However, to obtain consistent responding from the PC and RA channels, simple pressure is not sufficient. For these channels, it is necessary to provide a stimulus that has repeated onsets and offsets; vibration has proved to be an ideal stimulus for this purpose. The tactile response to vibration has been extensively investigated, and it has been determined that response to vibration in different frequency ranges is most likely mediated by different mechanoreceptors. **Figure 2** shows tactile sensitivity to vibration, as a function of vibration frequency. Current models of vibrotactile response postulate that the PC is responsible for the U-shaped portion of this curve, covering frequencies above about 40 Hz. Maximum sensitivity to vibration is seen at around 250 Hz. Threshold measures in the middle-frequency range (from about 10–40 Hz) are

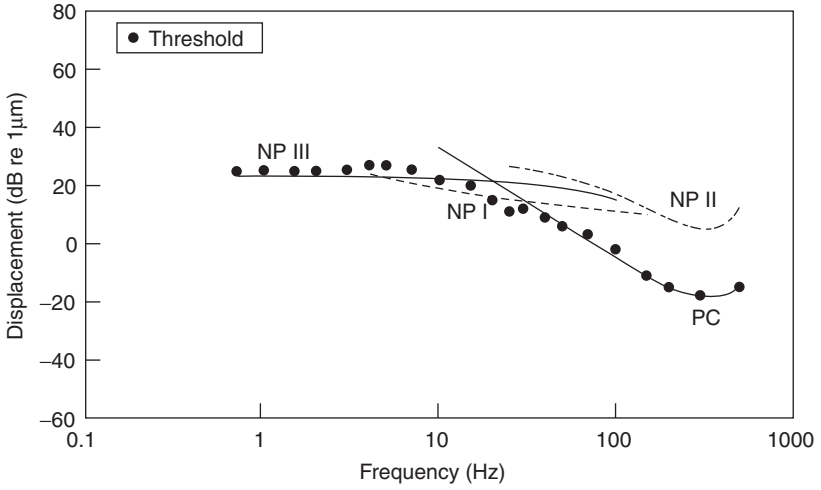

Figure 2 Threshold for detection of a vibratory stimulus applied to the thenar eminence (palm), for different frequencies of vibration. PC, Pacinian corpuscle; NP, non-Pacinian. Reprinted with permission from Bolanowski SJ, Gescheider GA, Verrillo RT and Checkosky CM (1988) Four channels mediate the mechanical aspects of touch. *Journal of the Acoustical Society of America* 84: 1680–1694, © 1988, Acoustical Society of America.

thought to be mediated by the MEI (labeled NP I, or non-Pacinian I, on the figure). The lowest frequency portion, labeled NP III, is assumed to be the MRK, and the high-frequency, high-amplitude curve labeled NP II may be the RU, serving the SA II afferent fibers.

Measures of intensity response indicate that the tactile system has a dynamic range, or range between threshold and uncomfortable stimulation, of 40–50 dB. Current physiological studies suggest that firing rate in the primary afferents may be the primary code for intensity perception. Temporal sensitivity measures produce varied results, depending on the task employed. In the best case, temporal resolution on the order of 3–5 ms has been observed.

In response to thermal stimulation, the tactile system again shows variation in sensitivity depending on the area and location stimulated. In measuring temperature sensitivity, the typical task involves detecting a change in the temperature of an area of skin from its previous temperature. Under the best circumstances, changes in skin temperature of as little as 0.003°C have been measured. The detection of a temperature change, however, depends on the initial temperature of the skin. Over a range of temperatures, between approximately 28 and 37°C, the body adapts to the skin's temperature, such that it is perceived to be neutral. This neutrality is referred to as physiological zero. Thus, detection of temperature changes from an initial neutral point may vary considerably, depending on the neutral temperature.

Measurement of pain responsiveness is much more complex. Individuals vary widely in their sensitivity to pain, as well as in their willingness to report it. In addition, pain produced by stimulation in the laboratory (laboratory pain) evokes a very different response from pain produced by disease or injury (clinical pain). Furthermore, long-term or chronic pain may be perceived very differently from short-term or acute pain. The additional factors involved may be psychological, in that pain has emotional or affective components of anxiety, unpleasantness, or depression. Furthermore, if the pain results from a serious illness or injury that debilitates physical condition, the response to it may be different from short-term pain experienced by a healthy individual. One current theory of pain perception posits three aspects of pain: sensory or discriminative, motivational or affective, and cognitive or evaluative. As a result, the measurement of pain requires considerable resourcefulness on the part of the researcher. One technique that has yielded promising results in the evaluation of pain perception is signal-detection analysis, in which it is possible to separate sensitivity effects from response bias effects. Other approaches often focus on adjectival scales and questionnaires to get information about pain perception beyond simple detection. These scales involve sets of adjectives that fall into sensory, affective, and evaluative categories.

Changes in Tactile Response over the Life Span

The most comprehensive study of the effects of aging on peripheral receptor anatomy was that of Cauna in 1965, who examined changes across the entire life span in a group of some 200 persons ranging in age from birth to 95 years. He reported observations for PC, MEI, MRK, and free nerve endings.

PCs, according to this report, begin development in the fourth fetal month, and are fully formed before birth. In infants, PCs are numerous and oval in shape, with a length of 500–700 μm. During the course of life, the number of PCs decreases steadily, and the receptors themselves change in size and appearance. Increases in size with age are accompanied by the addition of lamellae, or layers, that give the corpuscle an irregular shape and an onion-like appearance. The spaces between lamellae contain collagen, free cells, and blood vessels. The result of these added lamellae is the extension of the axon's myelin sheath inside the cell. The receptor segment of the nerve fiber also increases in length. By late in life, there are far fewer PCs than were present in the infant or even the young adult, and those that remain are large and irregular in shape.

The MEIs, which are found in the dermal papillae, have a spherical shape in the infant, and are some 25 μm in diameter. In young children they are relatively numerous, with a density of up to 70 per mm^2, and begin to assume a cylindrical shape, with a firm attachment to the epidermis. At this point in life, the nerve endings are neurofibrillar networks. In young adults who do not engage in heavy manual work, these networks are maintained. However, in individuals with a history of manual labor, the nerve endings develop into long, winding terminals of much larger diameter. With aging, the epidermal attachment is reduced, and the corpuscles take on a radically different appearance. Continued longitudinal growth over the life span results in a coiling of the receptor and a disarrangement of the nerve endings. Taking all coils into account, an individual MEI can reach a length of up to 1 mm. These changes are easily observable by middle age. With advanced age, some corpuscles undergo atrophy and are lost, with density reports as low as 4 per mm^2. Up to 90% of MEI receptors can be lost in very old individuals. The remaining corpuscles show terminal nerve fibers that branch repeatedly, producing long, winding filaments with an irregular organization. It is possible

that this ramification of nerve fibers is the result of inactivity in old age.

MRKs are also very numerous during late fetal life and can cover almost the entire epidermal undersurface. In infants, they become restricted to the undersurface of the intermediate ridge of glabrous skin. MRKs undergo relatively little change in structure over the course of life, remaining relatively densely distributed even in old age. However, some disks can enlarge in an uneven fashion, resulting in an altered appearance compared to the circular disk shape of infancy and young adulthood.

The free nerve endings, arising from medium-size myelinated fibers, undergo the least change over the life span. In elderly individuals, their appearance, number, and distribution are very similar to that of younger persons. However, changes in psychophysical measures thought to be mediated by free nerve endings do show some changes with aging, so the lack of obvious difference in appearance may not indicate functional changes in the activity of free nerve endings with age.

Psychophysical studies of tactile response as a function of age have not been pursued as actively as might be desired; thus, there is still a considerable amount of research needed to specify in detail the changes in tactile function with aging. Early reports indicated a decrease in sensitivity to light touch with increasing age. More recently, a series of studies has focused on changes in vibrotactile sensitivity across the life span. Measurements of vibratory threshold indicate a systematic decrease in sensitivity with age, starting quite early in life. Elevations in threshold have been observed even between 10- and 20-year olds, in both longitudinal and cross-sectional studies. By the age of 65, thresholds at 250 Hz, the frequency at which the tactile system is most sensitive, can change by as much as 20–25 dB. **Figure 3** shows the systematic change in vibrotactile thresholds by decade. As can be seen, the greatest loss of sensitivity occurs for higher frequencies, which are thought to be mediated by the PC. As mentioned, PCs decrease substantially in number in aging individuals, and those remaining assume a large and irregular shape. The loss of PCs most likely underlies the changes in vibrotactile sensitivity that are observed for frequencies above 40 Hz. At first it was believed that there was not a similar elevation in threshold with age in the lower frequency range, but recent results suggest that sensitivity also declines for these frequencies, just not as dramatically as for the higher frequencies. An additional consideration here is the fact that PCs have been shown to modify their response when skin temperature is altered. PCs show maximum sensitivity at fairly warm temperatures and have elevated detection thresholds when skin is cooled. Many aging individuals have lower body temperatures, and it is possible that this could affect the response of the remaining PC population. The MEI corpuscle does not show great sensitivity to temperature variation, however.

A number of hypotheses have been proposed to account for decreased sensitivity to vibration with aging. In addition to changes in the number of receptors, as mentioned above, other possibilities include altered receptor morphology, decreases in the number of spinal root fibers, dietary deficiencies in older persons, decreases in circulation, decreases in nerve conduction velocity, and general changes in the aging nervous system.

Magnitude estimation of the perceived loudness of suprathreshold vibratory stimuli indicates that older

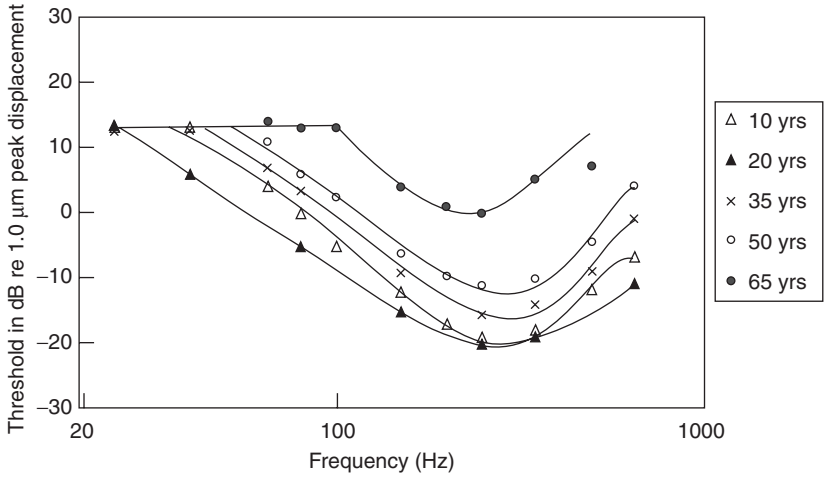

Figure 3 Changes in threshold detection of vibration, across age groups. Reprinted from Verrillo RT (1979) Change in vibrotactile thresholds as a function of age. *Sensory Processes* 3: 49–59, with permission from Elsevier.

individuals have simply shifted their entire dynamic range (i.e., both threshold and suprathreshold stimuli are perceived less acutely). Although results are mixed, it is generally believed that most individuals do not exhibit a phenomenon similar to that of auditory recruitment in which the dynamic range of the system is much smaller than would be predicted based on the threshold elevation.

Temporal resolution is also affected by aging. Measures of persistence, which is the duration over which a stimulus has an effect on perception, are longer in older persons. This result has been interpreted as indicating that the activity of aging neurons to a stimulus lasts longer than for neurons in younger persons. This result is supported by data from studies of temporal masking, a paradigm in which a previously presented stimulus interferes with the detection of another, target stimulus (forward masking), or in which a stimulus presented after the target interferes with target detection (backward masking). Both kinds of temporal masking are greater in older persons, again suggesting greater persistence of neural activity in response to both the target and masking stimuli. This effect, like those of detection, is more pronounced at high frequencies.

Far less is known about changes in sensitivity to temperature with aging. Some studies have shown changes in the ability to detect a thermal stimulus, but others have not. One report indicates a decrease in the ability to distinguish between two temperatures in older persons, but overall, results are inconclusive. It is possible that differences in stimulus delivery methods, or in subject criterion, may have great effects on the obtained measures. For example, one study reported that older subjects were poorer at detecting a radiant-heat stimulus than younger subjects. The radiant stimulus does not actually touch the skin surface, eliminating mechanoreceptive cues that might be used by older persons to supplement thermal perception *per se*. Criterion effects are a consideration in all studies of older persons. Results from a variety of studies indicate that old persons tend to set a very conservative response criterion, and are reluctant to report the presence of a stimulus until they are very sure that it is there. This tendency could lead to the assumption that older persons simply have reduced sensitivity to the stimulus.

In measurements of pain sensitivity, two types of tasks have been evaluated: detection of onset of a painful stimulus, and the tolerance limit for pain. In older subjects, threshold for detecting the onset of a painful stimulus is not particularly affected by age, but mixed results are obtained in studies of tolerance limits for pain. In fact, some studies show that older persons are more tolerant of pain, and others show that older persons are less tolerant of pain. Furthermore, there are some indications that the effectiveness of analgesic drugs is greater in older persons. As mentioned, pain sensitivity is postulated to be controlled by free nerve endings, which do not show great changes in either number or morphology with age. Thus, the lack of difference in the detection of pain onset between older and younger persons is not surprising. The mixed findings regarding tolerance for pain are most likely affected by the same emotional and cognitive considerations as are inherent in any pain research, and at present no definitive statement about pain sensitivity and aging can be made.

Proprioception

Physiology

Sensations generated by the body that give rise to a knowledge of the location and movement of limbs in space are the province of proprioception. Technically, the appropriate term for the sensation of movement is kinesthesia, whereas proprioception is reserved for the knowledge of static limb position. In practice, however, researchers use the two terms interchangeably. Sensations of body location and movement are mediated by specialized sensory receptors, that convey information about joint angles, muscle length, muscle tension, and the rate at which each of these changes during movement. Historically, the physiologist Sherrington referred to proprioception as muscle sense.

Over the years, researchers in kinesthesis have ascribed to differing notions of which receptors actually provide the necessary information. At various times, the field has held that the crucial receptors are in the muscles, or in the joints, or both, or neither. The current position is that the most important receptors are indeed located in the muscles, with joint receptors playing a minor part.

In considering the information that is provided to the central nervous system from the receptors, two classes of input would be required for accurate sensing. First, information about the position of limbs, or their displacement, could be coded in joint angle. Second, movement cues could be coded in transient responses signaling rate or acceleration.

Possible receptors that have been examined as participants in the coding of kinesthetic or proprioceptive information have included mechanoreceptors in the skin, receptors in the ligaments or capsules of the joints, and receptors in muscle. In skin, the RU, which has been implicated in the SA II mechanoreceptive response, seems to respond also to

skin stretch, and to change its discharge rate in response to changes in joint position. However, RU density in most areas of skin is not great enough to provide detailed information about position, and activation of RUs in isolation does not produce any conscious sensation of position or movement. It is possible that they do contribute to position sense, but perhaps only in conjunction with other receptors. Furthermore, they may play a more important role at body sites that have a high density of RU innervation, such as the tongue or fingers. Studies where topical anesthetic has inactivated mechanoreceptor response in the fingers indicate that movement of the affected areas is also inhibited. This result suggests that the mechanoreceptors may contribute to kinesthetic sensibility, but only at certain body sites, since in some areas (e.g., the knee), topical anesthesia does not inhibit movement or kinesthetic awareness. An additional consideration is that tactile input from pressure mechanoreceptors, such as the MRK, can enhance the sense of position of a body part. For example, placing the fingertips on a table improves the salience of perceived location of the fingertips.

In the joints, ligament and capsule structures are well innervated with SA mechanoreceptors that show responses to stretch of the joint or to stretching or bending of the capsule. In ligaments, Golgi-type endings, which have a dense branching of nerve terminals, show a strong response to stretch when stimulated in isolation. However, in the intact preparation, these endings tend to fire only at the extremes of movement, rather than to any movement. This tendency has led researchers to postulate that the Golgi joint receptors may serve a protective function, to indicate when a limb has been moved too far. In the capsule, SA responses from Ruffini receptors occur to stretching or bending, and could signal some aspects of joint position. It should be noted that local anesthesia of joint receptors, delivered by injection, does not impair the performance of motor tasks.

In muscles, there are two candidate receptors for proprioceptive sensation. First, the Golgi tendon organ, which is a thinly encapsulated bundle of fascicles with a spindle-like shape, may signal information about muscle tension. This receptor is shown in **Figure 4**. Because the Golgi tendon has low compliance, it could in fact respond to muscle tension. It is clear that this information is of great importance for regulating muscle contraction, but not as clear that it signals position *per se*. However, it is possible that muscle tension information is fed to other receptors, to correct their position judgments.

The most likely candidate receptor for mediation of kinesthetic and proprioceptive sensation is the muscle spindle receptor, also shown in **Figure 4**. Muscle spindles consist of a bundle of 2–12 intrafusal muscle fibers in a fluid-filled capsule. These spindles receive both sensory and motor innervation, and in fact a substantial amount of motor control outflow from the CNS is directed to the muscle spindles, for regulation of muscle contraction. The number of spindles found in a muscle varies greatly, depending on the size of the muscle, from 4 or 5 spindles to over 500. Smaller muscles show a greater density of spindles. These spindles lie parallel to the main, or extrafusal, fibers. There are two kinds of intrafusal spindle fibers: the nuclear bag and nuclear chain fibers, distinguished by the arrangement of cellular nuclei. Sensory innervation of these spindles terminates in the center region, and stretch here activates potentials in the receptor endings. Contraction of the end regions of the muscle spindles changes the sensory function of the fiber but does not appear to add to overall muscle tension. Instead, these changes are used to signal length and rate of change of length information to the CNS. Two different kinds of spindle endings have been discriminated. These include primary endings, located at the middle of the spindle, and secondary endings, located just off the middle. The primary endings show strong responses to velocity of movement, as well as to muscle length, suggesting that they can signal both position

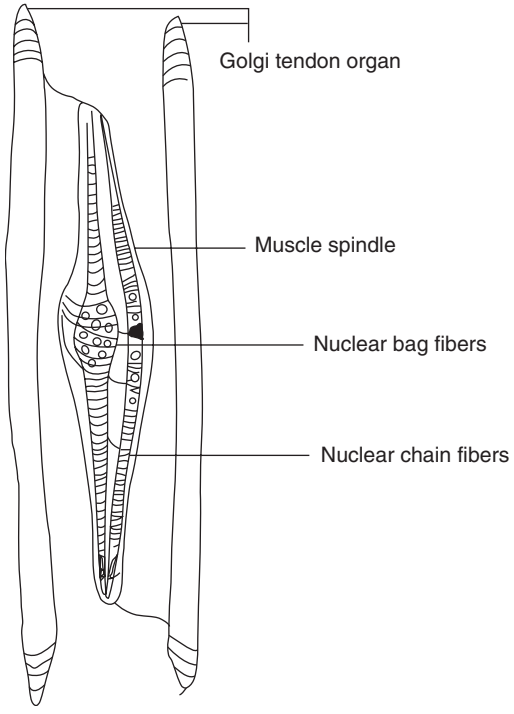

Figure 4 Schematic drawings of muscle receptors involved in proprioception, the Golgi tendon organ and the muscle spindle.

and movement. Secondary endings, on the other hand, provide primarily length responses. For both, the optimal stimulus falls between 0.1 and 2 Hz; it is important to note that few voluntary movements occur at rates higher than this. The fact that primary fibers show a temperature dependence in their responses but the secondary fibers do not, and that the secondary fiber firing rate is dependent on spontaneous rate but the primary fiber rate is not, suggest that the two kinds of fibers employ different encoding mechanisms. To some degree, differences in the contractile properties of the nuclear bag and nuclear chain fibers can account for observed response patterns in the muscle spindle afferents. In any case, it has been demonstrated that impulses from muscle spindles reach both sensory and motor cortex areas, reinforcing the notion that they may be the primary encoders for proprioceptive information.

Studies in which passive movement of joints is performed and the output of muscle spindles recorded indicate that muscle receptors signal movement over virtually the entire range of a joint's movement. The range appears to be about equally divided between the agonist and antagonist muscles governing the movement. Vibration of muscle tendons, which would activate spindle receptors, gives rise to a sensation that the joint is being moved, and further reinforces the notion that these receptors play a major role in kinesthesia.

Yet another putative source of information about joint and limb position and movement could be provided by motor commands that control voluntary movement. These commands, called corollary discharges, could provide information about the planned position of joints and limbs after the movement occurs. It is assumed that such corollary discharges, if present, arise at high levels in the CNS, at least above the cerebellum, which controls involuntary movements. There is some disagreement regarding the exact location of corollary discharges, but it is agreed that such discharges may be particularly important in the sense of effort that accompanies voluntary movement (*see* Motor Control).

At the CNS, a number of different possible codes have been considered as the primary input for proprioceptive sensibility. Rate-dependent discharges in the peripheral afferents, including differences in primary and secondary receptor activity, could signal directional information. It has been observed that primary receptors have a greater firing rate during muscle lengthening, whereas secondary fibers show a greater response to shortening. Although it is generally agreed that kinesthetic information is coded in firing rate, some difficulties have not yet been resolved, such as the fact that firing rate will increase with movement rate as well as direction and extent (*see* Neuromuscular System).

Psychophysics

In measuring the behavioral response of an observer to static position or movement, several kinds of information can be obtained. These include movement rate, direction, and extent, as well as the awareness of static limb position, the perceived amount of weight supported by a limb, the force produced by muscular contraction, and the sense of effort necessary to contract a muscle. Much of this work has focused on non-voluntary movements and placements of limbs. For example, in studies of passive limb extension, subjects can typically sense that movement has occurred before they can determine the direction of the movement. The dependent variable in such studies is often the displacement of the limb required for reliable detection of movement, at a particular movement velocity. Velocity is an important control, in that subjects tend to perceive very fast movements as having larger displacements than they do. However, errors are also more prevalent in very slow movements, and subjects show the greatest sensitivity to movement when velocity approximates the range in which most voluntary movements occur (in the vicinity of 5 m/s, for the hand). Accuracy is also dependent on the starting and ending position of the limb, and for different limbs, sensitivity may be better for movement in one direction than in another.

In general, proximal joints, those closer to the body, have greater sensitivity to movement than more distal ones, those at the extremities. This may be because in real movement, operation of the lever principle means that proximal joints move less than do distal ones. The poorest sensitivity to movement is seen for the finger, if displacement is the value measured. However, if responses are evaluated in terms of muscle stretch, different joints appear more similar in response, suggesting that the CNS may monitor muscle stretch rather than displacement per se.

Another measure of perceived movement is obtained via joint rotation. Minimum values for detection of passive joint rotation range from 0.2° for the hip to 0.7° for the first metatarsal phalange (big toe). These values, obtained from young adults, generally are higher by 0.1 to 0.2° in older persons. However, joint rotation detection is also rate dependent, and the range of movement necessary for detection of movement may be as high as 6°, depending on rate.

It is also possible to measure a more purely proprioceptive sensation, that of judged limb position, rather than movement. This measurement is more complex, of course, because responses to limb

movement necessary to change limb position could influence responding. Thus, rather than asking whether the limb has changed position following passive movement by the experimenter, some studies have employed a technique in which the subject is instructed to move the limb to a particular position, or to point to a position after a limb has been passively moved there. Results of such studies indicate that errors are greatest when the limb is passively moved and held there by the experimenter, and lowest when the subject actively moves the limb and actively maintains its position. Variability in positioning accuracy increases as the distance to be moved increases, and in general, subjects tend to overestimate short movement distances and underestimate long ones.

A major consideration in measuring proprioceptive sensation is the necessity of eliminating additional sources of information that might be used to signal limb position or movement. Two important sources of such information are visual and cutaneous inputs. Studies suggest that when vision is permitted, it dominates kinesthesis, even when the visual information is misleading, as when a distorted visual image is provided. In this case, position errors are made consistently, even though the kinesthetic information is maintained. At first, when vision and kinesthesis are decoupled in such a manner, they feel separated, but subjects quickly adapt to the changed visual environment, and the two modalities again feel congruent. In any event, measurement of proprioceptive feedback requires the elimination of visual cues, typically accomplished by blindfolding the subject. Elimination of cutaneous feedback from mechanoreceptors in response to passive movement of limbs has been approached in a number of creative ways. The most successful involve the use of air-bladder splints, which produce minimal cutaneous sensation, and topical ischemia, or reduction of circulation to a particular limb, which eliminates cutaneous sensations and induces a feeling of numbness in the limb after about 20 min. The need to eliminate these cues suggests that in normal activity, their inputs contribute to position sense.

Other studies have found that human subjects are surprisingly good at remembering previous limb positions, over remarkable periods of time. Up to 24 h later, subjects can indicate the position in which a limb was previously placed. This aspect of kinesthetic memory is of considerable interest, particularly given that most subjects are poor at verbal encoding of movement and position, and given the notion that verbal encoding of stimuli permits them to be retained in longer term memory.

Furthermore, it appears that individuals are better at judgments involving relative limb position (i.e., how one position is different from another) than those involving absolute limb position. This may be related to phenomena of postural persistence, the persistence of sensations related to a particular limb position. In any case, results indicate that judgments of the current position of a limb are influenced by its prior position, particularly if that prior position has been held for some period of time.

Researchers have also investigated the perceptual aspects of the sense of effort, or force, required to perform particular activities. There are two possible mechanisms for estimating effort: monitoring sensory inputs from Golgi tendon organ receptors in muscles; or monitoring motor command signals generated in the CNS (the corollary discharges discussed above). However, judgments of the heaviness of weights, for example, depend not only on the actual weight of the object, but also on the condition of the muscles involved in lifting it. Intervening muscle exertion that induces fatigue will make a lifted object seem heavier than before the exertion. Interestingly, the same phenomenon occurs for the perceived weakness of muscles following stroke, when peripheral muscle processes may in fact be unaffected. This result suggests that there is a central component in the estimation of weight, such that CNS signals generated during voluntary movement are also input to sensory areas, where they can influence perception. In addition, adaptation of heaviness occurs, for example, in situations in which light weights seem even lighter after heavier weights are lifted. And as for other proprioceptive functions, in the fingers cutaneous receptors may play a role; results indicate that anesthesia of cutaneous mechanoreceptors in the fingers also affects perceived heaviness.

Involved in the perception of effort is the sensation of muscle tension. Vibrating a muscle that facilitates or opposes the lifting of a weight will influence the perceived heaviness and thus the perceived effort of lifting. However, subjects do appear to be able to distinguish muscle tension from overall effort. If subjects are instructed to keep effort constant, the exerted force of muscle will vary with the object to be lifted. However, if subjects are instructed to keep tension constant, the exerted muscle force does not change. Weakening of muscles with injected curare will cause an increase in perceived effort.

In summary, humans seem to have good ability to sense limb position and limb movement, as well as judge the degree of effort required in task completion. Under normal circumstances, these sensations are influenced by visual and/or cutaneous inputs, at least at some body sites. In measuring the integrity of

kinesthetic sensibility after injury or disease, a number of tasks have been employed. Some of these are also used in assessing the effects of aging on proprioceptive sensation, and will be discussed in the next section.

Effects of Aging on Proprioception

It has been well documented that motor performance becomes slower and less accurate with age. However, opinion is divided on why this occurs. One hypothesis is that a decline in the quality of sensory input associated with movement results in a deterioration of motor performance. Thus, researchers have taken an active interest in changes in proprioceptive and kinesthetic sensation associated with aging.

Studies of the effects of aging on kinesthesis indicate that passive movement thresholds for the knee, hip, and ankle were as much as twice as high for older subjects (over 50 years) as those for younger subjects (under 40 years). However, little difference in sensitivity was observed for upper extremities (hands, fingers). These differences between upper and lower extremities may be partially attributable to the fact that the ankle and knee are weight-bearing joints that may be more susceptible to aging effects. Other results indicate that older subjects have higher thresholds for detection of joint movements when movement rate is slow. For higher rates of movement, differences due to age are less apparent. In examining the tasks used in such studies, it can be noted that some tasks are more memory intensive than others. Specific evaluation of the effects of memory load on kinesthetic perception shows that when the memory demands are low, differences between older and younger subjects are minimal, but when memory load is increased, elderly subjects exhibit worse performance (*see* Memory).

Nonetheless, even relatively simple tasks, such as reproducing a passive movement, were found in some studies to be more difficult for older subjects. The problem with movement reproduction studies is that the subject must store the proprioceptive input from the first movement in order to complete the matching movement. Some researchers have argued that immediate reproduction of a movement of one limb with the opposite limb reduces the memory requirements of the task.

One study investigated differences in performance of younger and older subjects on two different tasks, one involving constrained movement and one involving preselected movement. In the constrained movement condition, subjects were instructed to match a passive movement controlled by the experimenter, and in the preselected movement condition, subjects could select a movement that they wished to match. Results indicated that older subjects were much worse than younger ones in the constrained movement condition, showing many errors in matching experimenter-controlled passive movement. In the preselected movement condition, however, older and younger subjects performed similarly. Interpretation of these data was based on the notion that preselected movements can benefit from the corollary discharges that accompany voluntary movements, but passive movements cannot. If the older subjects' proprioceptive sensibility were reduced, performance in the constrained movement condition would be impaired, but the ability to use corollary discharge information in the preselected movement condition could compensate for any decreases in proprioceptive afferent function, such that performance would not necessarily suffer. In younger subjects, such corollary discharge facilitation is not needed, because proprioceptive input is sufficient for performance.

Many studies of aging and proprioception have focused on changes in the ability to maintain balance, or postural control. Numerous experiments have demonstrated that older subjects exhibit increased postural sway, and increased tendency to lose balance when stress is placed on the system, due to a slower initiation of balance control movements. One difficulty with such studies is the need to separate the effects of aging per se from the effects of decondition of muscles associated with reduced activity and possible subclinical pathologies in elderly individuals.

Postural control, under normal circumstances, involves the coordination of inputs from several systems, both motor and sensory. The strength and condition of effector muscles involved in balance, as well as the range of motion of knee, hip, and ankle joints will affect postural control. In addition, sensory inputs from kinesthetic, visual, cutaneous, and vestibular systems may play a role in the maintenance of balance. A number of studies have investigated the interactions of visual and vestibular factors in postural control, by selectively eliminating factors in tasks where balance is challenged by perturbation of a platform on which subjects stood. In general, it appears that in the average adult, the influence of visual cues was most evident at low perturbation frequencies, less than 0.1 Hz. Vestibular function is divided in its effects: the otolith organs respond maximally below 0.1 Hz for postural sway, but the semicircular canals, which mediate angular acceleration, are most responsive above that range. Cutaneous inputs could respond well above 1 Hz.

Results for younger adults indicate that postural sway increases by about 50% when the eyes are

closed, as compared to open. Postural sway is also increased when the head is placed in an odd orientation, affecting vestibular inputs. Lower extremity ischemia, induced by applying a blood pressure cuff at the ankle, eliminated cutaneous sensation, and also resulted in increased postural sway. These data indicate that all of these systems could contribute to postural control. However, researchers argue that if any two of the systems are intact in the young adult, balance can be maintained. Reflexive responses appear not to be affected by these other modality inputs, but instead seem to be organized in advance based on past experience, and are not flexible in implementation. A more continuous monitoring mode seems to be more dependent on visual, vestibular, and proprioceptive input for the ongoing maintenance of balance.

Studies comparing performance of younger and older subjects in postural control tasks show that older subjects can maintain balance as well as younger ones when conditions were not stressful, but that under stressful conditions, such as a greater degree of platform perturbation, older subjects were more likely to lose balance. In addition, although all subjects showed some deficits when inputs from other sensory modalities were limited, older subjects showed greater impairment of balance control. Modifications of vestibular or cutaneous inputs via the methods described above were very disturbing to older subjects. Both younger and older subjects were most affected by elimination of visual inputs. Furthermore, when two sensory input sources were disturbed simultaneously, older subjects showed severe deterioration of postural control, far greater than was seen for younger subjects. The implications of these results are that older individuals rely more heavily on input from additional sources, such as visual and vestibular modalities, to maintain balance, in the face of decreased proprioceptive sensibility. When these additional sources are eliminated, balance fails (*see* Balance, Posture and Gait).

Interestingly, attempts to correlate decreases in proprioceptive, visual, cutaneous, and vestibular function with postural sway measures have not indicated strong relationships. For example, visual acuity was not associated with degree of postural sway, except to the degree that both show decreases with age. Vibration detection by cutaneous receptors was related to postural sway, but did not correlate with proprioceptive measures. Finally, vestibular functioning was only weakly related to postural sway. The lack of strong correlations here should not be misinterpreted, however. It is possible that the detection measures used here would not show deficits correlated to postural sway, but this does not mean that declines in sensory ability at suprathreshold levels might not contribute to increases in postural sway. Furthermore, some investigators believe that decreases in postural control with aging are mediated more centrally, at some point where peripheral inputs are integrated. This notion is reinforced by the finding that in many cases, the longer-latency, voluntary corrections to balance are more affected in older persons than are short-term, monosynaptic reflex corrections.

Summary

Overall, results indicate that both touch and proprioception are susceptible to the effects of aging, and that declines in function can be observed for many tasks. For touch, sensitivity to vibration shows a systematic decline with age, and the perceived intensity of vibratory stimuli is also reduced at suprathreshold levels. Some reports also indicate reduced sensitivity to thermal stimulation, together with a general decrease in body temperature in older persons. In addition, pain sensitivity in older persons also appears to differ from that of younger persons, although differences in response criterion may underlie some of this difference. In many cases, these psychophysical changes are accompanied by decreases in number and density, and changes in morphology, of cutaneous receptors, particularly the PC and MEI.

Proprioceptive and kinesthetic function also appears to decline in older persons, although care must be taken to rule out declines in muscle condition due to inactivity. Threshold for detection of limb movement and the ability to reproduce changes in limb position seem to be worse for older persons, particularly in situations in which proprioceptive memory load is high. Postural control, an important consequence of proprioceptive sensibility, is also impaired in older persons, especially when balance is challenged. It appears that older individuals maintain postural control by relying more heavily on inputs from multiple sensory modalities, including visual, vestibular, and cutaneous sensations, to compensate for reductions in proprioceptive input, and that when these sensations are eliminated, postural control is more strongly affected than in younger persons.

There is a pressing need for further research into the physiological mechanisms and behavioral function of the senses of touch and proprioception, both in younger adults and in older adults. A better understanding of how these modalities are affected by age could lead to strategies to remediate or avoid these deficits, improving quality of life for older persons.

See also: Balance, Posture and Gait; Memory; Motor Control; Neuromuscular System; Pain and Presbyalgos.

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V

Vision

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Glossary

Acuity – Ability to resolve fine detail, usually in stationary, high-contrast targets.

Age-Related Maculopathy (ARM) – A visual disorder involving atrophy of the photoreceptors and neurons within the central retina; also known as age-related macular degeneration.

Contrast Sensitivity – Ability to detect luminance differences, usually between spatially contiguous surfaces.

Dark Adaptation – Increase in the visual system's light sensitivity in low illumination.

Glaucoma – An age-related visual disorder involving the loss of peripheral vision due to excessive pressure within the eye.

Optic Media – Transparent anterior components of the eye responsible for focusing images on the retina.

Presbyopia – Age-related loss of the ability to alter the refractive power of the lens to focus objects at varying distances.

Retina – Sensorineural structure in the posterior of the eye that contains the photoreceptors (rods and cones) and neural elements that transform retinal images into neural code.

Saccades – High-velocity, largely ballistic eye movements used to fixate different objects in visual scenes.

Useful Field of View – Visual area over which targets can be recognized and localized without eye or head movements.

Introduction

The normal, progressive changes that occur in vision as we age can make it more difficult to perform everyday visual tasks, especially those that have to be carried out under demanding viewing conditions such as dim lighting or low contrast. Some of the changes are due to age-related alterations in the optic media of the eye, others to sensorineural changes in the retina, visual pathways, and brain. The effects of the latter, however, are likely to be observed later in age (45 to 55 or so) than the former.

Although far less common than the visual changes experienced as a normal aspect of aging, serious visual disorders that can degrade well-being and mobility are also more prevalent in old age. Disorders such as these presumably account for research showing that vision loss is a commonly reported fear of aging.

The Aging Visual System

Optical Changes and the Retinal Image

A curved, transparent continuation of the sclera, the cornea at the front of the eye provides approximately two-thirds of the optical power needed to focus an image on the retina. Age-related changes in the cornea are usually moderate in extent. There tends to be some increase in corneal curvature and thus refractive power, primarily along the horizontal axis, and some increase in the cornea's tendency to scatter light.

The primary purpose of the pupil is to maximize the eye's depth of focus by maintaining the minimum size needed for ambient light levels. It also plays a secondary role in adjusting the level of light admitted into the eye. As we age, the diameter of the pupil decreases, a change referred to as pupillary or senile meiosis. As a result, the older eye admits less light than its younger counterpart under comparable illumination conditions. Because the difference in pupil size is more pronounced under dim light than bright light, older observers are especially prone to be disadvantaged by reduced lighting relative to their younger counterparts. A smaller pupil, however, also

enhances retinal image quality in the older eye by reducing light scatter and optical aberration and by increasing depth of focus.

By changing its sphericity via the ciliary muscle, the lens of the eye is able to adjust its refractive power to focus on closer or more distant objects. This adjustment process, known as accommodation, is steadily eroded with age by age-related hardening of the lens (lenticular sclerosis). Whereas a young child may be able to adjust the eye's focus by 18 to 20 diopters, by age 60, virtually all accommodative power is lost. Unless the observer was already quite near-sighted (i.e., myopic), the associated recession of the near point of vision (presbyopia) will demand added focusing power in the form of reading glasses, bifocals, or trifocals for near tasks. The lens also yellows and becomes less transparent with age, especially so for short wavelength light (i.e., blues and greens).

Around age 60, the average retina receives only about one-third as much light as it did at age 20. About two-thirds of this loss appears to be due to the older eye's smaller pupil, and about one-third to the increased opacity of the lens. Lens changes also increase light scatter markedly, an effect that makes older observers more sensitive to glare from strong light sources such as the headlights of oncoming vehicles at night.

Optically correctable errors in image formation, in particular far-sightedness (i.e., hyperopia) and astigmatism, are increasingly likely with age and contribute to the prevalent use of corrective lenses in older observers. Hyperopia results when the optic media are weak relative to eyeball length, making it difficult to focus on nearby objects. Large-scale epidemiological studies show that the prevalence of hyperopia increases with age; some also report the increase to be greater among women than men. Conversely, the prevalence of myopia or nearsightedness tends to decline with age.

In astigmatism, the eye's focus is irregular, usually because the refractive power of the cornea is greater for one orientation (i.e., axis) than another. Astigmatism is labeled depending on the orientation along which the eye has its greatest refractive power and clearest vision. If the eye has more power at vertical orientations it is termed with-the-rule astigmatism; if power is greater along the horizontal plane, it is termed against-the-rule astigmatism. Eyes with greatest focusing power between the vertical and horizontal are said to manifest oblique astigmatism. Epidemiological studies indicate an increase in the prevalence and severity of astigmatism among both men and women in the later years. There also appears to be a fairly consistent change toward greater rates of against-the-rule and oblique astigmatisms and a reduced likelihood of with-the-rule astigmatism. These changes likely reflect the age-related increase in the cornea's horizontal curvature. Without an appropriate cylindrical lens correction, older observers will have difficulty seeing vertically oriented target elements clearly.

The Aging Retina and Response to Light

Aging is associated with a pronounced loss of rods, the photoreceptors that predominate in the peripheral retina and are responsible for low-light (scotopic) sensitivity. Cones, the receptors that mediate fine detail vision and color perception at high ambient light (photopic) levels, are concentrated in the central area (macula) of the retina. Their density appears to be much less affected by aging than that of rods. Consistent with the loss of rods and their supporting retinal structures, scotopic sensitivity declines with aging about twice as fast as photopic sensitivity. Dark adaptation, the increase in visual sensitivity with falling light level due to the regeneration of cone and rod photopigments, also appears to progress more slowly in the older eye.

Photoreceptor response is processed initially in a retinal neural network of bipolar, amacrine, and horizontal cells and then is passed on to the retinal ganglion cells that compose the optic nerve for transmission to the brain. Several studies have reported significant age-related reductions in the number of retinal ganglion cells serving the macular region of the retina, and also in the number of axons in the optic nerve. These neuroanatomical changes appear to be accompanied by corresponding reductions in the retina's electrophysiological response.

The Visual Pathways and Brain

The optic nerve carries the neural information from the retina on to the lateral geniculate nucleus (LGN), the relay station for visual information in the thalamus. From there, it is conveyed to the primary visual cortex (V1). In the healthy older brain, there seems to be relatively little change in the density or size of LGN and V1 neurons. There is some evidence of functional deficits, however. These include slowing in visual transmission, reduced capacity to track rapidly changing stimuli, and in cortical cells, reduced selectivity for stimulus orientation and direction. Alterations in the neurochemical characteristics, synaptic organization, diminished intracortical inhibition, and/or demyelinization in the visual pathways have been suggested to explain these deficits. Such neural changes may also contribute to a functional decline in the extrastriate areas responsible for

higher-level visual functions. Even when no cell loss is apparent, imaging research reveals a tendency toward reduced efficiency and less specialization in the extrastriate cortical areas responsible for higher-level visual processing.

Color Vision

Although color vision losses can be severe in the presence of an eye disease (e.g. cataract, age-related maculopathy), a moderate linear increase in errors on color discrimination tests is characteristic of the healthy aging eye. Such errors tend to occur along the so-called blue-yellow rather than the red-green axis. This means that the typical older observer is most likely to experience difficulty distinguishing between colors that contain trace levels of blue or yellow, especially under conditions of low illumination. Much of this loss appears to be due to yellowing and darkening of the crystalline lens. Senescent changes in each of the three cone types (red, green, and blue) also appear to contribute to the age-related decline in color discrimination.

Age-related color vision changes are often sufficient to affect everyday visual tasks. Older observers report colors as less colorful or saturated, and tasks that depend on color coding (e.g., discriminating medicine bottles) can be more difficult for older observers, particularly in dim lighting.

Eye Movements

Three sets of extraocular muscles allow us to move our eyes to optimize different aspects of visual function, including fixation and acuity, balance, and the allocation of attention. Some eye movements are reflexive, while others are the result of goal-directed intent. Two generally voluntary eye movements that have been investigated in the elderly are smooth pursuit and saccades. Smooth pursuit movements, as the name implies, are those fluid movements made to track a moving object. Saccades are quasiballistic, high-velocity movements made to change the direction of gaze and attention. Smooth pursuit eye movements are slower in the elderly, with the result that there is more retinal blur for quickly moving objects. Saccadic eye movements are slowed in onset latency and are less accurate, at least when distractors are present and upward movements are required. What follows is a more detailed discussion of recent work in saccadic behavior.

Saccadic eye movements are readily executed in response to a peripheral onset (e.g., a flash of light) that elicits a prosaccade. In what is called an antisaccade task, observers are asked to move their eyes in the direction opposite this peripheral onset. This requires inhibition of the reflexive prosaccade. Some studies have found that the elderly make more errors and have slower correct responses in the antisaccade task. There is continuing examination of whether this reflects a lack of inhibitory control or a failure to hold in working memory the parameters for the correct eye movement.

In what is known as oculomotor capture, saccades are made to a unique stimulus, even when observers know that they are irrelevant to the task. The most robust capture obtains for rapid peripheral onsets. Older and younger adults show equivalent oculomotor capture when a single onset distractor is presented during visual search.

It is not only unique items that interfere with the accurate execution of saccadic eye movements. Saccadic averaging, also known as the center-of-gravity effect, occurs when saccades to an intended target are pulled toward neighboring objects. Older adults demonstrate greater saccadic averaging, with the result that they will need to program a second, smaller-amplitude eye movement in order to fixate a target. Thus, if rapid and accurate saccades are needed, visual clutter should be reduced.

Aspects of Visual Function

Spatial Vision

One of the more frequently studied aspects of spatial vision is acuity, the smallest detail that can be reliably resolved, usually in a high-contrast target or optotype. Under ideal viewing conditions, the best acuity for a human observer can be as low as 0.5 minutes of arc; under normal conditions, acuity averages 1 minarc in younger people. This corresponds to 20/20 vision. Older adults who are wearing appropriate optical correction for the test distance (this is not the usual case) can typically obtain 20/20 vision until their 60s, at which point detail vision deteriorates. Age differences in acuity are magnified at near distances because of the lack of accommodation. Additionally, acuity in older adults is relatively worse when the stimuli are of lower luminance contrast.

A more comprehensive index of spatial vision involves measuring an individual's contrast sensitivity function, sensitivity to small differences in luminance for coarse, intermediate, and fine detail (i.e., spatial frequency). For humans, contrast sensitivity is at a maximum between approximately three and five cycles per degree of visual angle under daylight viewing conditions. The high frequency cutoff under these same conditions, corresponding to acuity, is about 30 cycles per degree.

Older adults, even those wearing their best optical corrections for the viewing distance, show systematic

declines in contrast sensitivity (CS) that are more pronounced for intermediate and higher spatial frequencies. In low luminance conditions, age deficits emerge at low spatial frequencies as well. Age-related changes in contrast sensitivity do not appear to be caused by optical aberrations. Instead, they are related to changes in retinal illuminance and neural integrity. Interestingly, recent research shows that age-related losses in CS are predictive of later acuity decline.

Another facet of spatial vision is depth perception, which is critical for a variety of actions including walking, grasping, and collision avoidance. There are a myriad of cues, both environmental (e.g., texture gradient) and physiological (e.g., stereopsis), that mediate depth perception. Several studies suggest that the elderly are less able to make use of binocular disparity to judge depth at near distances, but there has been little additional work in this area.

Human spatial vision has evolved so that details are seen best when they are imaged on the foveal (i.e., central) portions of the retina. However, a great deal of important visual information is obtained from peripheral vision. This information is used to guide eye movements and attention, to facilitate the perception of depth and motion, and to maintain balance and postural stability. Traditional measures of peripheral function often assess a person's visual field when the stimulus is a small target (e.g., a light onset) presented in an otherwise empty field. Static visual fields are diminished from approximately 180 to 140 degrees, but this may be an artifact of low luminance in the perimeter. Perhaps more important functionally are age-related differences in the useful field of view (UFOV), the area over which peripheral processing occurs in cluttered scenes, often when attention is divided over more than one task. The UFOV is quite task dependent, often very small relative to classically measured visual fields, and can predict performance on everyday tasks such as driving. Current research centers on whether age-related declines in the UFOV are best described as a general loss in sensitivity or one that is exacerbated as targets are presented more peripherally.

Hyperacuity is a term applied to a range of visual tasks involving the discrimination of relative location, motion, or shape that produce thresholds as low as a few seconds of arc. Exceeding the optical resolution of the eye as well as the limits of cone size and density, such precision is attributable to the neural pooling of photoreceptor information at higher levels of the visual system. Thus, hyperacuity tasks can be useful for measuring the effects of age-related sensorineural change separate from those due to optical losses.

Age differences on static hyperacuity (e.g., vernier acuity) tend to be small relative to those seen for dynamic tasks (e.g., oscillatory motion discrimination). Vernier hyperacuity refers to the judgment of the alignment of two or more clearly visible targets; when the targets are separated rather than abutting, the task is also referred to as extrapolation acuity. Everyday examples include reading a thermometer or aligning a ruler with an edge. Although most studies have reported that aging has little or no effect on Vernier or extrapolation tasks, some recent studies have reported an age deficit.

There is no such conflict in the findings from studies of age differences on dynamic hyperacuity tasks. They show that the minimum displacement of a target needed to discriminate it from a stationary stimulus is increased among older observers, even when no age difference is seen on a static version of the same type of task.

Processing Visual Events: Sensitivity to Time and Motion

The traditional technique for measuring the ability of visual system to track rapidly changing visual events is to measure the critical flicker frequency (CFF), the minimum frequency at which a bright pulsating light patch appears to be on steadily rather than flickering. The CFF threshold declines gradually to about age 60 and more rapidly thereafter. A large part of this loss appears to be due to reduced retinal illumination associated with normal age changes in the optic media and pupil. Indicative of reduced temporal resolution in the senescent visual system, however, changes in the visual nervous system also contribute to the age-related deficit on the CFF task.

Because it provides a more comprehensive assessment of the visual system's temporal sensitivity than the CFF task, more recent studies measure the effects of aging on flicker sensitivity using the temporal contrast sensitivity function (tCSF). The temporal analog of the spatial CSF, the tCSF task varies the depth of luminance change (i.e., contrast) of a small (2–5 degrees) target sinusoidally around a mean baseline luminance level over a wide range of frequencies. Initial research on age effects on the tCSF reported that the age deficit increased with flicker rate. There was also a leftward shift of the overall function toward lower flicker rates, suggestive of a decline in the speed of visual functioning. Subsequent research, however, provided evidence that this shift is explained by reduced retinal illumination. When this was controlled for, most of the age difference was eliminated; the remainder has been attributed to reduced sensitivity in the temporal visual channels.

Older adults are less capable of detecting the onset of motion, the direction of motion, and motion-defined surfaces as well as discriminating differences in speed under near-threshold conditions. However, for stimuli well above contrast thresholds, there appear to be no meaningful age differences in detecting the direction of a single, directional 'jump.' Additionally, estimates of subjective speed appear to be age invariant for suprathreshold speeds, at least under relatively simple viewing conditions.

Responses to moving stimuli can be primed by prior exposure. In contrast to directionally sensitive motion phenomena such as the waterfall illusion, visual motion priming is an enhancement of perception in which the primed stimulus is more likely to be seen as moving in the same direction as that of the priming stimulus. Older adults show less two-dimensional (2D) and three-dimensional (3D) visual motion priming than the young, and it has been suggested on the basis of psychophysical and imaging studies that this deficit reflects changes in temporal sensitivity in middle temporal regions of visual cortex.

Motion parallax refers to the fact that when we fixate on a particular distance while moving through a stationary world, retinal image velocity is inversely related to the distance of an object from fixation. Parallax is a powerful monocular cue to depth and also plays a critical role in the perception of 3D shape. While older adults are able to use parallax to mediate depth perception, they exhibit deficits in detecting the presence of 3D surfaces and identifying 3D shape via parallax.

Signals arising from several sources (e.g., the extraocular muscles and the brain) help us to maintain the veridical perception of a motion. However, there are circumstances in which these mechanisms fail. The Filehne illusion refers to the observation that stationary objects appear to move opposite to an eye movement. The Aubert-Fleischl phenomenon occurs when objects appear to move more slowly when we smoothly pursue them. Older adults appear to show the same Aubert-Fleischl effect as the young, at least for low image speeds at which age differences in pursuit gain would not be a factor. However, at least for stimuli of short duration, the aged demonstrate a reduced Filehne illusion. The reason for this deficit is unclear.

Biological motion refers to the motion pattern that unfolds as people engage in activities such as walking and running. Although relatively little work has been done in this area, it appears that older adults can accurately perceive biological motion associated with gross activities such as walking, even at durations of only 0.25s and when the moving object is occasionally occluded.

Another ecologically important type of motion perception involves time to contact (TTC), a subjective estimate of the time remaining before two objects in relative motion would cross paths. Clearly, TTC judgments are important for avoiding collisions while driving. Several studies indicate that the elderly consistently underestimate TTC, a difference that should put them at less risk for accidents. However, it also appears that the elderly are less accurate in judging whether a collision will occur. It is unclear how these two trends interact to influence safety.

Finally, there are practical reasons for asking whether aging affects the ability to perceive detail in motion. Conventionally, research involving dynamic visual acuity has found that the elderly age differences in acuity increase at high rates of target motion. Dynamic contrast sensitivity is also negatively correlated with age, particularly for higher spatial frequencies. While age differences in smooth pursuit gain could account for these findings, the observation that age deficits are minimal under high contrast/luminance conditions suggests that the problem lies within the optic media.

Attention

Attention can be thought of as the deployment of processing resources to task-relevant objects, locations, or subtasks. It can be stimulus driven, as when we orient to a loud sound, or goal directed, as when we selectively attend to signage because we are trying to locate an office building. Short-lived attentional demands are common. Generally, we attend to the contents of our clothes closet for only a moment or two in order to pick out a shirt to wear. On other occasions – over-the-road driving is one example – we must maintain an attentive state for long, dull periods of time.

One of the most frequently employed tasks for investigating age differences in selective attention is visual search, which is often executed in complex and cluttered scenes containing a great amount of distraction. For many search tasks, performance slows and becomes more error prone as the number of distractors increases – the display size effect. In some instances, however, search is relatively independent of the number of items in the display. This occurs when targets are defined by only one salient feature or when people have been provided with a great deal of practice.

A substantial body of research, anecdotal, experimental, and applied, documents the difficulties that older adults experience with visual search. These problems tend to increase with display size, particularly when the object being sought is visually complex

and similar to the distractors. They are also exacerbated when there is limited time to search the scene, when targets are presented in the periphery, and when other tasks must be performed simultaneously. Aging effects under these conditions are manifested often as a proportionate increase in reaction time, consistent with generalized slowing.

There are numerous ways in which the use of attention appears to be age invariant. Older adults have little difficulty attending selectively to simple features like orientation, color, direction of motion, and depth. They also make as much or more use of advance information about where to search. Additionally, they seem to learn simple search tasks at the same rate as their younger counterparts and seem to be relatively flexible in modulating the features to which they attend, as long as some higher-order rule can be used to guide search.

Most attention tasks demand that observers allocate processing resources over relatively short periods of time when targets occur regularly and frequently. In contrast, vigilance, or sustained attention, demands a longer duration of attentional allocation when signals are uncommon. Most of the gerontological research on vigilance indicates that there are no age differences in overall vigilance performance or the vigilance decrement, the decline on performance with increased time on task. There is some indication that the elderly are more prone to vigilance problems when event rates are high and visual quality is low, but this is not a consistent finding. A few recent studies suggest that age differences in vigilance may emerge in ecologically valid tasks such as driving. There are no data on inhibitory control, goal maintenance, or task-switching in sustained attention tasks.

Age-Related Visual Disorders

As we age, the likelihood of a disabling visual disorder increases, dramatically so after age 65 or so. Two levels of visual disability are generally distinguished: low vision and legal blindness. Low vision refers to a vision loss of sufficient severity to interfere with the ability to carry out everyday tasks and is often defined as a best corrected acuity level between 20/40 and 20/200. Legal blindness is defined as a corrected acuity of 20/200 or worse in the better eye and/or a visual field smaller than 20 degrees. Epidemiological studies indicate that low vision or blindness affects more than 3 million adults aged 40 and over in the United States alone and that the future prevalence of such disabling losses will increase markedly as the proportion of elderly people rises. Age-related losses of sight can result from a primary eye disease or can occur as the secondary consequence of some other age-related illness. The four disorders that most commonly threaten sight in old age are cataract, age-related maculopathy (ARM), glaucoma, and diabetic retinopathy.

Cataract or opacification of the lens is the leading cause of visual impairment among older adults. Cataracts appear to be a near-universal outcome of old age; close to 70% of adults in the United States exhibit clinically significant cataracts by age 80. By absorbing and scattering light, cataracts reduce image luminance and contrast. This in turn impairs acuity, color discrimination, and contrast sensitivity and increases susceptibility to glare. Risk factors for cataract in addition to age include exposure to sunlight, steroid use, previous intraocular surgery, smoking, and diabetes. Fortunately, cataracts are readily treated by the replacement of the natural lens with an artificial version (i.e., an intraocular lens [IOL]).

Age-related macular degeneration (ARMD), the leading cause of irreversible visual blindness among the elderly in developed countries, causes a loss of central vision. Although the specific cause is not known, it results from the loss of photoreceptors associated with changes in the underlying retinal pigment epithelium (RPE) and Bruch's membrane that support their metabolic needs. The 'dry' or early form of ARMD leads to some impairment of acuity; the late form causes severe acuity loss. When the late form of ARMD is accompanied by a proliferation of fragile and often leaky new retinal blood vessels, it is referred to as the exudative or 'wet' form of the disease. While laser photocoagulation, photodynamic, and/or antioxidant treatment may slow the neovascularization, they cannot reverse the vision loss. The severe loss of acuity, color perception, and contrast sensitivity with ARMD can impair the patient's ability to carry out even the most basic tasks of everyday life.

Glaucoma is a progressive loss of peripheral vision due to damage to the optic nerve where it exits the eye. Although there are marked individual differences, glaucoma usually occurs in association with elevated intraocular pressure. There are two types of the disease, both of them associated with a buildup of aqueous humor that is produced continuously by the ciliary body. In open angle glaucoma, the aqueous humor is prevented from exiting the anterior chamber of the eye via the canal of Schlemm. In closed angle glaucoma, the prolapse of the iris against the lens prevents aqueous humor from circulating from the ciliary to the front of the eye. The patient is often unaware of the presence of glaucoma until quite late in its progression. In addition to a narrowing of the visual field, or 'tunnel vision,'

glaucoma can cause loss of contrast sensitivity, night vision, motion perception, and color vision. Regions of blindness (scotoma) can accumulate and eventually may lead to complete blindness. Tasks needing effective peripheral vision such as walking, obstacle avoidance, and driving can be impaired early in the disease. Moderate glaucoma often responds well to drugs that reduce aqueous production or enhance its outflow; closed angle glaucoma is also sometimes treated by creating a small hole in the iris (an iridectomy) to equalize pressure on either side of the iris.

Diabetic retinopathy (DR), the fourth leading cause of legal blindness in adults over 65 in the United States, is caused by diabetes-induced changes in the retinal vasculature. In its common initial form, DR is associated with a swelling and some leakage from the retinal capillaries, which impair vision. For a minority, these changes can progress to rapid retinal neovascularization with bleeding into the vitreous humor, retinal scarring, and even retinal detachment. This outcome is more likely for those who need to take insulin. The loss of acuity, color, and contrast sensitivity, scotoma, and reduced visual fields that can result from DR can make everyday tasks difficult. In addition to management of the underlying diabetes, lasers can be used to anneal leaking blood vessels. If necessary, panretinal photocoagulation can be used to reduce neovascularization by lowering the overall metabolic demands of the retina.

Low vision and blindness can make it exceedingly difficult to carry out such instrumental activities of daily living (IADLs) such as handling money, shopping, or taking medication and can even affect the basic ADLs such as bathing, feeding, or dressing. In assisting low-vision patients it is important to address both their visual loss and their adaptation to that loss. For example, visual functioning may be improved through the use of low-vision optical aids, good lighting, large-print materials, and simplified floor plans and marking the edges of stairs with high-contrast strips. Social service interventions that foster peer and family support in combination with psychosocial and rehabilitation programs can help to reduce social isolation and enhance overall quality of life.

Vision in Everyday Life

Age-related visual pathologies such as glaucoma and ARMD often have a profound impact on a person's ability to participate in important activities such as walking, reading, driving, and engaging in a variety of work-related and leisurely activities. Even in the absence of pathology, the elderly report visual problems with everyday tasks such as driving and use of the World Wide Web. Their self-reports are often highly insightful and generally consistent with the findings from lab and clinical studies.

Surveys conducted over the past two decades have asked healthy older people about the visual problems they experience in common tasks such as driving. The difficulties that emerge are consistently related to events occurring too quickly vis-à-vis their ability to respond, search, and deal with unexpected events, light sensitivity (e.g., dim displays and glare), and near vision. The self-reports of older drivers are consistent with changes in their driving habits. For example, older adults reduce driving distances generally and are particularly reluctant to drive at night, in poor weather, during high-volume times of day, and along higher-speed roadways and unfamiliar routes. The self-reports are also consistent with the accident profile of older drivers, in which merging, yielding right of way, and negotiating intersections weigh heavily. Certainly, many of the changes in visual function that have been summarized previously should be related to driving performance. These include dynamic acuity and contrast sensitivity, glare recovery, peripheral vision, motion and depth perception and visual attention. Unfortunately, with relatively few exceptions such as in studies of the UFOV (*see* Driving Behavior), attempts to use measures of visual function to predict accident involvement in the aged have not met with much success, and so the critical issue of licensure for at-risk older drivers remains a research and policy challenge.

Older adults represent the fastest-growing group of users of the Internet and World Wide Web. They use these resources to communicate with family and friends, plan activities, develop and maintain interests, obtain health information, and find psychosocial support. Several studies have suggested that access to the Internet and web can enhance self-efficacy, build social support, and reduce depression and isolation. Still, even a cursory examination of websites leads to the conclusion that usability issues abound and that age-related declines in visual function can interact with poor web design to render usage error prone and frustrating. A small but growing literature indicates that the elderly have difficulties with font size and style, color usage, clutter and crowding, finding links, recovering from 'broken links,' and navigation in general. There are a few empirical studies linking web performance with visual function, and guidelines have been proposed by various agencies to reduce visual demands of web resources so as to make them more accessible to the elderly. It will be important in future years to evaluate the usefulness of these guidelines and to build a

stronger empirical base for directly testing the influence of individual difference variables and design features on elder use of these important tools.

See also: Driving Behavior.

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Volunteer Activity by Older Adults ☆

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Glossary

Formal Volunteering – Any activity intended to help others that is freely provided through a charitable, religious, civic, or similar organization and for which no pay or other type of material compensation is received.

Independent Sector – A non-profit coalition of over 800 foundation, corporate, and voluntary organization members with interests in philanthropy and voluntary action.

Informal Volunteering – Any activity intended to help others that is freely provided on an ad hoc basis by an individual and for which no pay or other material reward is received.

Intensity of Volunteering – Hours spent per week or per month in either formal or informal volunteer activity.

Volunteer Participation Rate – Incidence of volunteer activity within a specified population or group.

Introduction

Volunteer activity is generally defined as any activity intended to help others that is provided without obligation and for which the volunteer does not receive pay or other material compensation. Volunteers usually provide such assistance through a religious, charitable, or civic organization, but their assistance also can be given on an ad hoc or non-organizational basis. This article uses the broader definition of volunteer activity that includes assistance to others (except immediate family members or relatives), which is either organized and formal or episodic and informal in nature. Because there is no standard definition of what constitutes volunteer activity, it is somewhat difficult to provide a precise picture of trends in volunteerism in the United States. I use data from national surveys as well as information from studies on various aspects of volunteering to provide some general trends and findings about volunteerism and the older population in recent decades. The article concludes by looking to prospects for expanded volunteerism among older Americans in the future.

☆ Any views expressed in this article are those of the author and do not necessarily represent formal policies of the American Association of Retired Persons.

Trends in the Prevalence of Volunteering

Although they use somewhat different definitions of volunteering, national surveys conducted during the last two decades in the United States indicate that the prevalence of volunteering increased steadily during the late 1970s and throughout the 1980s, but declined slightly since 1990. At the same time, the composition of the volunteer population has changed – a reflection of wider trends in society as a whole. One of the more noteworthy trends is a recent increase in the incidence of volunteering among older Americans.

A series of national surveys conducted in 1988, 1990, 1992, and 1994 by Independent Sector (IS) provides the most consistent set of data measuring volunteer activity among adult (aged 18 and over) Americans. The IS biennial surveys explicitly define volunteer activity as "not just belonging to a service organization, but actually working in some way to help others for no monetary pay." This definition, which includes both formal and informal volunteering, is the most common way that volunteerism is measured and discussed.

As shown in **Table 1**, the prevalence of volunteer activity increased during the 1980s, reaching a peak of 54% in 1989–90. Since then, however, overall rates of volunteerism decreased to 48% in 1993–94. (The IS surveys, conducted in March, ask about volunteer work "during the previous 12 months"; resulting in data covering most of the previous year and the first-quarter of the year in which the survey was taken.)

Also shown in **Table 1** are volunteerism data for 1973–74, based on a national survey conducted by the Census Bureau for ACTION, the federal agency for volunteer service. It is important to note, however, that the ACTION survey restricted its data only to "unpaid volunteer work for a group ... or ... any other type of organization" that regularly uses volunteers – a distinctly more restricted definition than in the IS surveys. Although **Table 1** includes these earlier data, the rates are not directly comparable to those for the later years. I include them because they indicate the prevalence of formal volunteering in 1973–74. An analysis by Susan Chambre of the recent IS survey data showed that less than 10% of the respondents who say they volunteered did so solely on an informal basis. Applying this difference to the 1973–74 survey results would adjust upward the rates of overall volunteerism at that time. But even after this adjustment, it appears that volunteerism – both formal and informal – was less prevalent before the 1980s.

Factors Related to the Likelihood of Volunteering

Definitive explanations for these changing rates of volunteerism are elusive. There are few in-depth national studies on the complex aspects of volunteering. Most studies are descriptive in nature and confined to small populations of specific programs, making it difficult to generalize about volunteerism in the United States during the past three decades.

Table 1 Volunteer participation rates by annual income, employment status, and educational attainment (%): United States 1973–94[a]

	1993–94	*1991–92*	*1989–90*	*1987–88*	*1973–74*
Total	48	51	54	45	24
Household income					
Under $10,000	34	32	30	23	17
$10,000–$19,999	37	38	42	40	29
$20,000–$29,999	53	51	56	50	—
$20,000 and over	—	—	—	—	37
$30,000–$39,999	56	56	64	51	—
$40,000–$49,999	55	67	67	44	—
$50,000–$74,999	61	61	63	57	—
$75,000–$99,999	58	63	62	50	—
$100,000 and over	68	74	74	62	—
Employment					
Employed	52	59	60	49	25
Unemployed	41	43	45	38	17
Retired	41	34	39	35	22
Education					
High school or less	37	38	42	34	19
Some college	53	62	66	56	32
College grad or more	67	77	74	64	43

[a] Sources: For 1987–94: Hodgkinson VA, and Weitzman MS *Giving and Volunteering in the United States*. 1994 edition. Washington, DC: Independent Sector (1994); for 1973–74: ACTION (1975). *Americans Volunteer: 1974*. US Bureau of the Census, Washington, DC.

Although there is no clear 'model' that consistently predicts rates of volunteering, who volunteers, or what motivates volunteer activity, enough information is available from both national surveys and case studies to indicate which factors are most commonly associated with volunteerism.

Some researchers believe that volunteer activity increases during periods when the economy is growing or steady, but decreases during periods of economic sluggishness or recessions. This theory is based on the assumption that people are more likely to seek out opportunities to help others when they themselves feel economically and emotionally secure. The IS survey data in **Table 1** provide limited support for this thesis. The incidence of volunteer activity in the United States increased from 45% to 54% of all adults during the last half of the 1980s – a period of steady economic growth – and began declining during the recessionary period of 1991–92 (51%). But the most recent survey indicates further declines in these rates (down to 48% in 1993–94) even though the economy was growing once again.

This anomaly may be related to the type of volunteering that has declined. Although not shown in **Table 1**, the latest decline in the proportion who volunteer is largely due to lower incidence of informal volunteering. The proportion of respondents who gave assistance to individuals or organizations on an ad hoc or informal basis declined from 23% in 1991–92 to 17% in 1993–94. In contrast, rates of formal volunteerism remained steady during the same period. The surveys also indicate that those who are members of various organizations – religious, civic, charitable, educational – are significantly more likely to do formal volunteering than those who do not belong to such organizations.

Organizational membership is the bedrock of volunteering, providing a relatively steady stream of formal volunteers. In contrast, informal volunteering is less consistent and more prone to variation over time. This type of volunteer work is more sensitive to economic conditions, or, more precisely, people's perceptions of their economic well-being. National opinion polls in recent years indicate that a large proportion of Americans feel insecure about their economic well-being and uncertain of their future security, despite the relative health of the economy. Those perceptions may reflect economic realities that are not evident in standard macroeconomic measures. Recent studies indicate that during the 1990s real wages and income were stagnant for most middle-income Americans, declined for those in the lowest income quintile, and increased for those in the highest income quintile. These economic trends and a growing sense of insecurity among many Americans coincide with the recent downturns in volunteerism (*see* Economics: Society).

The link between volunteerism and economic factors is supported in many studies indicating that income and education are strongly related to likelihood of volunteering. **Table 1** shows that the highest rates of volunteering are among those who are better educated, wealthier, and employed. These persons are also most likely to be members of communal organizations through which most formal volunteering occurs. Multivariate analysis by Robert Harootyan and Robert Vorek of national survey data on volunteerism found that education and income are the two strongest predictors of volunteering. Their model also shows that – all else being equal – volunteerism is determined by (in descending order of influence) altruistic attitudes (e.g., belief in sharing one's benefits with those who are less fortunate), having positive perceptions of the contributions that others make to society, being aged 35–44, being satisfied with one's quality of life, having a larger household, and being married (the latter is reflected in **Table 2**).

Their findings stress the simultaneous influence of socioeconomic and attitudinal factors on volunteerism. In addition, being married, having a large household, and/or being in a child-rearing age group suggests that the presence of a spouse, children, or

Table 2 Volunteer participation rates by gender and marital status (%) and average hours per week in volunteer activity: United States 1973–94[a]

	1993–94	*1991–92*	*1989–90*	*1987–88*	*1973–74*
Total	48	51	54	45	24
Gender					
Male	44	49	52	44	20
Female	51	53	56	47	26
Marital status					
Married	52	56	59	50	27
Single	41	48	44	40	20
Divorced, separated, or widowed	40	36	47	34	15
Hours spent in volunteer work per week	4.2	4.2	4.0	4.7	9.0

[a] Source: See **Table 1**.

other family member increases the likelihood of volunteer activity. These characteristics are likely to generate greater awareness and more opportunities for volunteering, especially through educational, religious, and civic or charitable organizations. Such opportunities may be due to a family member's awareness of or involvement in community-based organizations. A child's school-related activities or participation in extracurricular or recreational programs often leads to parental involvement as volunteers, which may be truly voluntary or the result of implicit expectations or explicit requests for volunteer assistance.

The relevance of household size is also related to findings from the IS and other surveys, which indicate that simply being asked to volunteer greatly increases the likelihood that persons will do so. This is especially true when persons are asked by relatives, close friends, or co-workers. Being a member of a large household naturally increases the chance that individuals will not only hear about volunteer opportunities but be asked to do volunteer work. The IS studies indicate that more than four out of five persons (82%) who are asked to volunteer do so. In contrast, only one out of five persons (21%) who are not asked to volunteer actually do so.

Not only is volunteerism induced by family circumstances and employment, it is also strongly related to involvement in educational and religious organizations. By far the most frequently mentioned vehicle for volunteer activity is a religious organization. Most studies show that 45–50% of all volunteers donate some or all of their time through a synagogue or church. The second most prevalent vehicle for volunteerism is educational organizations, which are mentioned by one-fourth to one-third of all volunteers. Other types of organizations – hospitals, civic groups, and charitable organizations – are less common avenues for volunteerism (*see* Religion and Spirituality).

To summarize, volunteers are most likely to be better educated, financially comfortable, employed, satisfied with the quality of their life, concerned about the welfare of others, younger adults, married, and living in relatively large households (probably comprising two or three generations). These findings indicate the complex manner by which socioeconomic, attitudinal, and structural factors influence volunteerism in contemporary American society. Those who are most integrated into the social fabric and the economic structure of society are most likely to be volunteers.

Trends in Volunteerism in the Older Population

The findings about volunteerism in general also help to describe and explain age-specific and age-related trends in volunteer behavior. Elderly persons (aged 65–74 and 75+) and those who are retired are less likely than non-elderly persons and those who are employed to be volunteers (see **Table 3**). The data are consistent with the general thesis associating volunteerism with socioeconomic status, household size, and degree of involvement in communal life. Until recently, aging and old age were often viewed negatively and characterized by the loss of important roles such as parent and paid worker. Old age usually brings lower income upon retirement. Households headed by older persons tend to be small. The older population's average level of educational attainment has been significantly lower than for persons under age 65. For many older persons mobility becomes restricted and community activities decrease (*see* Retirement).

We are not surprised, then, that elderly persons are less likely to volunteer than non-elderly persons. Yet some observers have suggested that old age should be a time of increased volunteer activity precisely

Table 3 Volunteer participation rates by age (%): United States 1973–94[a]

	1993–94	*1991–92*	*1989–90*	*1987–88*	*1973–74*
Total	48	51	54	45	24
Age group					
18–24	45	48	43	42	18
25–34	46	53	62	45	—
35–44	55	61	64	54	—
25–44	—	—	—	—	30
45–54	54	56	56	48	25
55–64	47	49	51	47	21
65–74	43	42	47	40	—
75 and over	36	27	32	29	—
65 and over	—	—	—	—	14

[a] Source: See **Table 1**.

because of the role losses that occur. This perspective assumes that volunteer activity is a key way for older persons to fill an assumed void in their lives. But numerous studies indicate that role loss is unlikely to induce volunteerism among the elderly. In a comprehensive examination of the potential for 'unpaid productive roles' (i.e., volunteerism) by older Americans in the future, the Committee for an Aging Society concluded in 1986 that unpaid work does not appear to be a substitute for paid work. The report emphasized that societal values and the meanings attached to paid and unpaid work are notably different. One does not take the place of the other. The committee's conclusions are consistent with the findings that volunteerism is strongly associated with being employed rather than unemployed or retired. Chambre's thorough analysis of volunteerism and the elderly reached the same conclusion. Volunteer activity is supplemental to and intrinsically different from paid work.

Moreover, the IS surveys and a 1991 national survey on senior volunteerism sponsored by Marriott Senior Living Services indicate that neither loneliness, lack of activity, extra time, nor desire for socialization is a strong motivator for volunteerism. Rather, the desire to help others – altruism – and to make a real difference in the well-being of the community – a sense of accomplishment or self-fulfillment – are significant determinants (along with income and education) of who volunteers. In addition, positive perceptions of the importance of charitable and civic organizations, as well as active involvement in religious institutions are highly likely to influence who volunteers, whether old, middle-aged, or young.

For older persons, however, volunteerism can be restricted by social and physical barriers. Poor health is most often cited by older persons as the reason for not volunteering. Health problems, combined with limited economic resources (lack of reimbursement for costs associated with volunteering affects lower-income persons the most), lower educational levels, and transportation difficulties all serve as barriers to volunteering by older persons. The Committee on an Aging Society also stressed that biases against older people, especially when combined with negative orientations towards some type of volunteer work, serve to thwart elder volunteerism.

Finally, a life-course perspective is necessary to fully understand the relationship between age and volunteerism. People do not suddenly become 'old' at age of 65 or 70. Nor do values, attitudes, ethical standards, political philosophies, and general personality traits change significantly with age. Similarly, people who have not been active volunteers during most of their lives or those who have not had positive role models of volunteer behavior in their youth are unlikely to become volunteers when their parental responsibilities end, when they retire, or when they reach age 65. As with other characteristics, volunteerism tends to be a lifelong activity that begins in youth and continues in old age.

Viewed from the life-course perspective, volunteerism among younger age groups in earlier decades becomes important for understanding volunteerism among today's older population. The attitudes, experiences, and behaviors of specific birth cohorts provide clues to volunteerism in the future. Although the data are limited, most surveys show that volunteering in general was less prevalent before the 1980s, regardless of educational level, income, marital status, or age (see **Tables 1, 2** and **3**). Thus, the lower incidence of volunteering among those who were aged 35–54 in the 1970s is reflected in the lower proportions of volunteers among those aged 55–64 and 65 and over today. The life-course perspective, when combined with knowledge of the key predictors of volunteering, provides a basis for projecting changes in the volunteer activity of older Americans (*see* Life Course).

Implication for Future Volunteerism by Older Americans

Will significant age differences in volunteer activity persist in the future? I think not. As discussed above, birth cohort differences help explain the lower rates of volunteerism among retirees and persons aged 65 and over through the early 1990s. But differences by age and employment status in volunteer participation rates appear to be lessening. As seen in **Table 1**, between 1987 and 1992 the difference between the volunteer participation rates of employed and retired persons increased from 14 percentage points to 25 percentage points. By 1993–94, however, the difference declined to its lowest level – 11 percentage points – during the years covered by the IS surveys.

More significantly, the direction of the changes within these groups has reversed. Since 1991–92, the volunteer participation rate among employed persons declined from 59 to 52% in 1993–94. For retired persons, however, the participation rate during this time increased from a low of 34% to a high of 41%. It is premature to suggest that this short-term change will continue as a long-term trend, but the degree of change in the rates of volunteering among retired Americans is very large. And because this change occurred in just 2 years, the possible influence of the trend toward lower average retirement age is not a factor, as shown by the age-specific data for those years.

The same pattern emerges in the age-specific rates of volunteerism. Since 1991–92, the proportion of volunteers decreased in each age group under 65, while the incidence of volunteering among those aged 65–74 increased one percentage point, reaching 43% in 1993–94. More dramatic was the increase from 27 to 36% for those aged 75 and over – the highest rate recorded for this age group in any national survey (the Marriott survey recorded 39% among those aged 75–79 and 27% among those aged 80 and over).

Although the volunteer participation rate of Americans aged 65–74 is still lower than for some younger age groups, it now approaches the rates of those aged 18–24 and 25–34. These trends cannot be explained simply by the aging of the US population. More complex processes influence the growing involvement of older persons in volunteering – processes that exemplify the 'coming of age' of today's older population and those who will soon reach their 65th birthday. This emerging trend reflects the changing characteristics of older Americans – characteristics that tend to make them more similar than dissimilar to the rest of the population.

I have emphasized that retirement does not induce volunteering and that employment is a predictor of it. It seems ironic, then, that the increasing labor force participation rates of women have constrained their level of volunteerism. The IS surveys indicate that, as with other population subgroups, volunteer participation rates have declined since 1990 for both women and married persons. Also, the number of hours that can be devoted to volunteer work has been constricted for those who traditionally have been the most active volunteers – women aged 35–64, especially married women. Among all women, the labor force participation rate surpassed 57% in 1993, compared to less than 50% in 1970. Most significant are the changes since 1970 in the employment rates for married women in this age range. Among those aged 35–44, the rate increased from 47% in 1970 to 75% in 1993. For married women aged 45–64, labor force participation grew from 44 to 60% during this period. These employment trends have reduced the incidence of volunteerism and the amount of time spent by those who do volunteer (especially for informal volunteering), except among those aged 65 and over (*see* Work and Employment: Individual).

Indeed, older Americans are in part making up for the reduced incidence and 'intensity' (hours spent per week or month) of volunteering by young-adult and middle-aged persons in recent years. The two trends may be serendipitous and not causally related, but the pattern is clear.

Other forces also have influenced the growing incidence of volunteerism by older persons. Significant changes in birth cohort characteristics that span less than two decades are the most likely reasons for the increasing rates of elder volunteerism in the 1990s. Amendments to the Social Security Act that introduced automatic annual cost-of-living adjustments for retiree benefits in 1975 have reduced the poverty rate among the elderly. Also, more than 40% receive some type of private or public pension payment. Similarly, the 30-year-old Medicare program has helped reduce a major fear of older persons – the potentially high burden of health-care costs. Thus, older Americans in general feel more economically secure today than in previous decades. But it is unclear if this sense of security will last. Older Americans now pay a higher proportion of their average income out-of-pocket for their health-care expenses than 30 years ago (22 versus 15%, respectively). Congressional proposals to dramatically reduce federal spending on Medicare are raising concerns among many elders.

As discussed earlier concerning Americans in general, perceptions of economic well-being and a sense of security allow persons to look beyond themselves and reach out to help others. Older Americans are no different in that regard. Altruism and a sense of accomplishment are important inducements to volunteering among all age groups. So, too, are socioeconomic characteristics other than income or perceived economic security. Among older persons themselves, those who are employed (whether full-time or part-time), married, and better educated are more likely to volunteer than are other older persons. Labor force participation rates have declined steadily for males and risen only slightly for females aged 55 and older during the last 20 years. The overall effect is to reduce their likelihood of volunteering. In contrast, a slightly higher proportion of older Americans are married than in previous decades, which increases their likelihood of volunteerism.

But the most significant and rapid change in birth cohort characteristics of older Americans has been educational attainment, which is the most influential predictor of volunteerism in the regression and discriminant analyses by Harootyan and Vorek. As recently as 1980, 43% of all persons aged 65 and over had less than 8 years of schooling, compared to 24% in 1993. Less than one-fourth (24%) had completed high school in 1980, but by 1993 more than one-third (34%) had done so. And in 1980, 17% had some college education or beyond, rising to 26% in 1993. This minor 'revolution' in the educational attainment of older Americans in less than 15 years promises to continue as new cohorts with higher

average years of schooling reach age 65 during ensuing decades.

The implications of this upward trend in educational attainment are highly significant for future volunteerism by older Americans. As the most influential predictor of volunteerism, educational attainment will foster new levels of volunteerism among older persons. Multivariate analysis indicates that after controlling for other factors, older persons with at least some college education are almost three times more likely to volunteer than those with a high school education or less. The educational trend also bodes well for increased volunteer activity by older persons that focuses on young people. Harootyan and Vorek found that disproportionately high percentages of elders with college degrees (37%) and education beyond college (28%) volunteer in programs benefiting youth, compared to 22% with a high school degree and 8% of elders with less than a high school education. An additional benefit from higher educational attainment among older Americans is its positive relationship to health status. New cohorts of older Americans who are both better educated and healthier than their predecessors will 'double' the likelihood of increased volunteerism.

Another factor is especially important regarding future prospects of elder volunteerism – the influence of religious organizations. Studies such as the IS surveys consistently point to religious affiliation and activity as important determinants of volunteerism. Harootyan and Vorek showed that volunteer activity through a religious organization increases with age, rising from 38% among those aged 18–34 to 54% among those aged 65 and over. As the average age of religious congregations continues to rise, so too will the concentration of older volunteers.

It is also possible that new cohorts of older Americans will not only be members of religious organizations but also more likely than their current age peers to be members of secular organizations. For reasons that are not clear, the typical older American today is less likely to be a member of secular organizations in the community. But middle-aged Americans have relatively high incidence of such memberships, which are expected to be maintained over their life courses. Should this pattern continue, the likelihood of increased formal volunteering by elders in the future is quite strong.

A 'hidden' indicator of the potential impact of more older volunteers is the multiplier effect of the time they devote to such activity (the intensity of volunteer time). The data from various national surveys during the last decade indicate that the average volunteer gives about 4 hours per week. The Harootyan and Vorek survey showed wide variation by age in average hours volunteered per month. The monthly average for all volunteers is 17 hours, compared to 26 hours for those aged 65–74. Even the oldest volunteers – those aged 75 and over – average 14 hours per month, the same amount as volunteers aged 35–44. Although elder volunteer participation rates are lower than most other age groups, the intensity of their volunteer time is the highest.

Past attempts to increase the number and proportion of older volunteers also may prove beneficial in the future. The federal government has administered a number of voluntary action programs to foster the availability of older Americans as a community resource. They are currently administered under the umbrella of the National Senior Volunteer Corps. Some of these programs have a second purpose – to provide a modest stipend for low-income older persons who would otherwise be unable or unlikely to volunteer. They also focus the volunteer effort on populations with special needs. The Foster Grandparent Program is targeted to children with special needs, whereas the Senior Companion Program promotes volunteer activity that assists elders who are isolated. The largest federal elder volunteer program is the Retired and Senior Volunteer Program, which accounts for almost 500 000 volunteers aged 55 and over who serve all age groups in communities throughout the nation.

Taken together, however, these government efforts provide only a fraction of the potential volunteer force within the older population. And cutbacks in federal spending are likely to constrict the growth of these programs. Helping to fill the void are new nationally oriented volunteer service programs. Most notable among them is the National Retiree Volunteer Center, which fosters the development of corporate and educational retiree programs that have the potential to recruit hundreds of thousands of new volunteers among the retired.

The effects of private non-profit initiatives, whether in a local community or on a national scale, can be profound. The potential resource they can tap within the older population is greater than most realize. Already, the American Red Cross notes that more than half of its volunteers are aged 55 and over. The Committee on an Aging Society reported that for every five older volunteers, there are another two older Americans who are willing to volunteer but do not. National surveys, such as the 1991 Marriott study, since then support that estimate.

The barriers to elder volunteerism discussed above provide some of the reasons why those elders are not volunteers. Embedded in one of those barriers – ageism – is a key element to promoting more volunteerism by older Americans. I already alluded to this

simple yet historically overlooked factor: people are far more likely to volunteer if they are asked (e.g., being in a larger household). Ageism, perhaps abetted by negative self-images, has kept many older persons who might otherwise volunteer from doing so. However, the changing socioeconomic characteristics of older Americans will increase their propensity to volunteer. Tapping that propensity may be no more difficult than simply asking them to help.

See also: Economics: Society; Life Course; Religion and Spirituality; Retirement; Work and Employment: Individual.

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W

Widowhood and Widowerhood

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Glossary

Anticipatory Socialization – In the process of anticipatory socialization to the role of widowed person, individuals who are not yet widowed engage in behaviors or have experiences typical of widowhood. The extent to which this occurs varies with age and the expectedness of widowhood, the duration of the spouse's fatal illness, and the forewarning of death.

Bereavement – The actual process of experiencing grief, mourning, and re-organization of one's life. Although some argue that bereavement cannot be assigned a specific amount of time, clinicians and researchers generally suggest that the process can take a full 2 years; some suggest even longer.

Social Support – That set of personal contacts through which the individual maintains social identity and lifestyle. Supports may be economic, tangible, or emotional in nature.

Introduction

Widowhood or widowerhood is both a status and a process. The status of widowhood is given to an individual who has not remarried following the death of his or her spouse. Widowhood is also a process of transition, progressing from the illness of the spouse (which may vary from lengthy to very short term) to the death of the spouse and related events involving burial and mourning, grieving, and reconstruction of one's social world.

Women who have experienced the death of their husbands are referred to as widows, and men who have been widowed are referred to as widowers. The experience of widowhood takes place within a variety of contexts: spatially (from one culture to another), temporally (within any one culture over historical time), and longitudinally (over the course of an individual's life time). Furthermore, the experience is defined differently according to subcultural definitions such as gender, ethnicity, age, and class. Other factors that influence the experience of widow- and widowerhood include the nature of the marital relationship prior to bereavement and the status of women in society. Variations from one society to another, and within societies, often reflect social and cultural norms surrounding death, mourning, and remarriage.

The focus on the female experience of widowhood has been so predominant that only comparatively recently has the word 'widowerhood' been included in some, but not all, English dictionaries. Indeed, in all societies, women are more likely to be widowed than are men, and the differential increases substantially with age.

The Changing Profile of Widowhood

In many countries, the proportion of the population aged 15 and over who are widowed is approximately 6%. Two factors typically characterize the incidence of widowhood in the population: its sex selectivity and its age-related nature.

Half of all marriages end with the death of the husband, but only one-fifth with the death of the wife. Among women aged 65 and over, almost 70% are widowed; the comparable figure among men is 22%. Because of this demographic reality, discussions of widowhood generally focus on women (*see* Demography). In the developed world, nearly half of women aged 65 and over are widowed, and this proportion rises to four-fifths of those aged 85 and over. On the other hand, fewer than one in five men is widowed at 65, although almost half of men aged 85 and over are widowed.

The discrepancy in age and incidence can be explained by three principal factors: biological, cultural, and social. First, in all societies men tend to die earlier on average than do women. Second, in most cultures, women tend to marry men who are several years older than they are (this is sometimes referred

to as the 'mating gradient'). These two factors combined mean that the likelihood of widowhood increases with old age and being female. However, the third explanation for the imbalance in gendered widowhood statistics is the social acceptance, and to some extent expectation, that a widowed man will remarry and will do so within 2 years of his loss. Not only are men far less likely than women to become widowed, they are also less likely than women to remain widowed. It is estimated than fewer than one in five widowers and one in ten widows do eventually remarry. It can be argued, therefore, that statistics on men's marriage status do not offer the complete picture since even in longitudinal studies, a man might be registered as married at each survey point but may have been widowed between waves of data collection. Research has shown that the older the widower, the less likely he is to re-partner, hence the apparently dramatic increase in the proportion of widowed men in the oldest-old age group. However, even among elderly persons, widowed men have remarriage rates over eight times higher those of elderly women.

Since the 1970s the average age at widowhood has steadily increased in many countries. Thus, widowhood is associated not only with women but also with old people. Almost three-quarters of the widows in North America are over the age of 65. The average age of the widowed population is 75 for both men and women.

The increased average age at widowhood is not a global phenomenon, however. The epidemic of HIV/AIDS in sub-Saharan Africa has meant a reduction in the average age of widowhood for both men and women. However, in these circumstances widowhood is more likely to be of short duration, partly as a result of remarriage patterns among younger generations. Also, when both partners are infected, as is frequently the situation, the period of survivorship is truncated.

Even in the developed world, life expectancy and average age at widowhood can vary widely among gender, ethnic, and socio-economic groupings. For men, but less so for women, there is a strong correlation between wealth and low morbidity (illness) and mortality rates. Men with higher incomes and high educational attainment live longer, healthier lives than low-income, poorly educated men. As a consequence, the experience of a surviving spouse, whether male or female, can be vastly different in widowhood, especially in relation to financial security. These findings must be interpreted with caution, however. A widow left with a large family house, reduced income, and altered standard of living can become what is termed 'equity rich, income poor,' inasmuch as she has valuable property but is unable to afford its maintenance and may be discouraged by adult children from selling their 'inheritance.'

Ethnic and cultural differences also mediate the experience of bereavement, not only in terms of age and pension poverty. Within some cultures, such as parts of the rural Indian subcontinent, for example, widows face a life of poverty and societal rejection.

Two other features characterize the experience of widowhood: the expectability of widowhood as a life event and the relative duration of widowhood in the lives of elderly people. Because most individuals in society marry, the experience of widowhood has been an 'expectable' life event of later life for most people; however, there is some evidence that this pattern is changing. Recent trends in North America and Europe indicate that growing proportions of older populations are married, declining proportions are widowed, and the percentage of older people who are divorced or separated is small but rising precipitously. Because of increases in the proportions of the population who are entering old age outside of marriage (because of having remained single or through separation and divorce without remarriage), the likelihood of being widowed in later life is in decline. Indeed, there is some suggestion that widowhood will, in proportional terms, become a less normative life event among future cohorts of women.

Because of the mating gradient referred to earlier, and the longer life expectancy of women, the average length of widowhood for women is considerably longer than for men. In many countries in the developed world, the average duration of widowhood is 6 years for men and approximately 15 years for women. However, there are recent changes in these long-term trends in differences in life expectancy between men and women. In many countries, the gender mortality gap is closing, because men's mortality rates are decreasing as a result of better standards of living and health promotion strategies. Nevertheless, with the aging of the baby boom generation and associated anticipated increases in the absolute numbers of widowed persons in the population, the careful attention of policy makers will be required to address the needs of many elderly widowed persons, and widows in particular.

Widowhood as a Relative Life Event

Widowhood is considered one of the most stressful of life events and role transitions. Although research findings are somewhat equivocal, the timing of widowhood in the life course and the duration of the spouse's final illness contribute significantly to the experience of bereavement. The experience of widowhood as 'on time' or 'off time' affects individuals in terms of their psychological preparedness, their opportunities for anticipatory socialization, and the

societal resources and supports available to them. The age at which a person experiences the death of the spouse is a very important feature of the experience of widowhood because of the way in which the person's life is embedded in other social roles at that point in time. Similarly, the duration of a spouse's final illness also influences opportunities for anticipatory socialization to the role of widowed person. However, this relationship appears to be stronger for the case of early, off-time widowhood than for widowhood in later life.

Many individuals take 2 to 4 years to adjust to the loss of their spouse (*see* Bereavement and Loss). Although the early period of bereavement is typically associated with profound psychological disorganization and feelings of status loss, widowhood also provides opportunities for personal growth and independence, and, for some, release from an unhappy union. Qualitative studies and narrative accounts of widowhood confirm that widowhood fundamentally involves a renegotiation of aspects of daily life and, as reported for women in particular, a reconfiguration of one's sense of self and relationship to others.

Research on the relationship between widowhood and morbidity and mortality is fraught with contradictory findings. Although there is evidence of short-term decreases in health status and perceived health following widowhood, long-term health appears largely unaffected. Despite early research findings of high mortality rates among widowers, more current epidemiological studies have found no significant relationship between bereavement and mortality. Findings of the long-term impact of widowhood on mental health are similarly equivocal, although the early bereavement period is generally associated with depression, mood alterations, disrupted sleep patterns, obsessive thoughts of the deceased, and disorientation. Nevertheless, the degree of disorganization produced by widowhood is influenced by many factors, especially by the degree of dependence upon a social network associated with the role of husband or wife and upon the level of commitment to that role (*see* Bereavement and Loss).

Despite the view of widowhood as a particularly stressful life event, most individuals adapt well over time, although the process of reconstruction of a new life and social order is for some a long and painful one. Many women, in particular, fare well in widowhood and underscore the point that widowhood is not necessarily a state of deprivation or deficit. For many people, widowhood represents a crisis not in the sense of a threat of catastrophe but rather a turning point, a crucial period of increased vulnerability and heightened potential. Many realize that potential, although as they advance in age and grow increasingly frail, the threat of becoming dependent looms large in their lives (*see* Life Course; Life Events).

Social Supports in Widowhood

The meaning and nature of social support has been extensively examined in the gerontological literature. There is strong evidence of a positive relationship between social support and health. The need for support in widowhood is by no means fixed. Thus, the types and sources of support beneficial at one point in the process of widowhood may not necessarily be appropriate at a later point in the transition. Researchers have also questioned the assumption of the inherent value of social support. Loose, low-density networks, rather than tightly bound, all-embracing networks, may be most appropriate in enabling widowed men and women to develop new social roles consistent with their new status.

Research findings indicate the predominant role of family ties in informal helping networks following widowhood. However, as many as one in five widowed persons report not having a single living relative to whom they feel particularly close. Clearly, there are many sources of variability in the experience of widowhood, all of which will influence the patterns of access to available social supports and their perceived benefit.

Adult children provide much of the assistance received by older widowed parents. But patterns of contact between widowed individuals and their adult children are not necessarily uniform, either among children or in terms of the duration of widowhood. Most contact is with daughters, and although the support of adult children is crucial during acute grief, it may become less salient over time as friends increase in importance.

Sibling relations hold a unique place in support networks in terms of their longer duration in comparison with other family ties and their essentially egalitarian nature. Research suggests generally strong patterns of emotional support between widowed persons and their siblings, especially sisters, although frequency of contact and exchange of aid may be comparatively low. Other extended family members, such as nieces and nephews, also act as viable members of the support networks of widowed people, especially in terms of emotional support. Research has also found that the memory of a deceased spouse can provide a form of support in widowhood.

Friendship relations change substantially with widowhood. Not distinguished by the feelings of obligation that characterize family relations, friendships – especially those with members of a married

couple – may not survive widowhood. The ability to make new friendships may indeed be an important indicator of how an individual is coping with the loss of a spouse. Self-help and mutual support groups represent particular kinds of peer relationships. Although typically utilized by only a minority of widowed people, such groups have been demonstrated to effectively reduce the distress of widowed people in intervention groups. However, formal organizational support groups are consistently underutilized by widows and are rarely used by widowers.

In relation to all these sources of support, the redefined personal resources and identity of a widowed person strongly influence the utilization of potential social supports. Recent research has documented the experience among some widowed people of what are called 'identifying moments,' the widows' sudden conscious awareness of their new status and the fact that their identity has changed. In any study of changes in patterns of social support in widowhood, the possibility of change in widowed individuals themselves as an influencing factor is an important consideration (*see* Social Networks, Support, and Integration).

Diversity in the Experience of Widowhood

Many factors distinguish the experience of widowhood for men and for women. The greater 'expectability' of widowhood as a life course event for women frequently leads to a mental rehearsal or anticipation of circumstances associated with being 'unattached' in later life. Although considerable research has debated whether the loss of a spouse is more difficult for men than for women, the meaning and consequences of death and widowhood for men and women under varying sets of circumstances remain little understood. The challenge of analyzing the effects of gender is complicated by the demography of widowhood, such that studies of widowed persons often result in samples in which only 13% are men.

Despite these research difficulties, studies have identified overall differences between widows and widowers in attitudes toward remarriage and in the issues that are most problematic to them in widowhood. Loneliness is a major problem for both men and women; financial resources are much more typically a concern for widows. Widows are far more likely than widowers to be poor in old age. Feelings of competency in the completion of household tasks and issues involving sexuality are more often reported as major areas of concern for widowers, although this may reflect cohort effects for older men in general (*see* Loneliness).

There are also points of contrast between widows and widowers on measures of social support. Overall, widowers report smaller support networks and less involvement with friends and family than widows. In negotiating their social worlds, widowers rely almost exclusively on themselves or their children. Many widows, by contrast, have much more extensive and diverse social networks. Overall, then, widowers appear comparatively disadvantaged in their ties to family and in their domestic skills, but both these patterns may be cohort specific.

Social isolation is a typical feature of life for elderly men who are 'unattached' in old age due to either widowhood or divorce. Research shows that older divorced men are even more likely to be socially isolated from family and friends and engage in more risky health behaviors, such as smoking and harmful alcohol consumption, than other groups of older men. In some Western countries, such as the United Kingdom, more men in their late 60s are divorced or separated (9%) than widowed (7%).

Until comparatively recently, less attention has been paid to men who are widowed. Research on widowers has principally focused on the health outcomes and psychological disorientation caused by an unanticipated disjunction: a husband does not expect to predecease his wife. There is a continuing debate on 'who suffers more,' widowers or widows. Research in Canada, the Netherlands, the United Kingdom, and the United States has examined the well-being and living conditions of older widows and widowers in order to establish gender differences in adaptation to conjugal loss. Remarkable similarities in the reported well-being of elderly widowed people have been noted. Availability of resources such as income, education, and freedom from limiting disability advantaged the widowers, but widows benefited from the support of close female friends and neighbors as well as adult children. Few significant differences were found in the reported personal relationship needs, although the relational patterns were different: the women tended to have more 'emotionally intimate' female friends. The men were content with male friends for 'sociability,' but also wished for a cross-gender romantic relationship. The men derived satisfaction from the presence of new partners or partner-like relationships and tended to depend more on adult children than the widows. While widowed women were disadvantaged regarding income, education, and health resources, they reported a degree of life satisfaction similar to the widowed men. It was concluded that this was because women had been socialized to greater flexibility and adaptability over the life course. This helped them with the major change brought about by widowhood and mediated the instrumental disadvantages.

An increasing number of widowed persons live alone, many of them residing in the same community and the same housing unit for many years. Although home ownership may be an important source of economic security for a widowed person, high housing-related costs may seriously undermine the financial benefits of ownership. In addition, long residential tenure, often for reasons of sentimental attachment to home as well as inertia at the prospect of relocation, may confine widowed men and women to homes whose physical characteristics are no longer appropriate to their needs and to a neighborhood that is no longer able to provide a supportive environment.

Widowed persons living in rural areas have marginally stronger supportive relationships with family and friends but often lack the economic resources and access to transportation available to the urban widowed. When relocation finally comes for those widowed in later life, it may be into an institutional setting. Although comparatively few elderly people are institutionalized, widowed individuals are proportionally overrepresented among those who seek institutional care in later life.

Childlessness does not appear to exacerbate the transition to widowhood. However, some studies note the distinctive experience of widowhood from a marriage that involved stepchildren. The challenges experienced by some of these widows in maintaining relationships with stepchildren can be an additional source of strain in the period following bereavement.

Competing demands associated with the performance of other roles or the experience of simultaneous transitions may also have an impact on the experience of widowhood in later life. Although the experience of retirement from the paid labor force is rarely coincident with widowhood, the loss of ongoing contact with work associates exacerbates the loneliness of widowhood for some individuals. Responsibilities involving providing care to dependent adult children or disabled parents may also complicate the transition to widowhood.

There is also little empirical support for the popular assumption of more extended networks and more involvement in those networks by widows and widowers with strong ethnic group identification. However, comparatively little is known about how societal norms and expectations of bereavement and widowhood shape the experience in non-Western societies. An exception is the well-known but long-banned traditional Indian practice of suttee (the expectation that widows would immolate themselves on their husband's funeral pyre). While this practice is no longer carried out, an Indian widow does undergo a form of 'social suttee' whereby she is considered 'as good as dead' and must endure crippling poverty and destitution, especially if she is without sons. In Botswana, the practice of 'seantlo' requires that a widow marry her dead husband's brother and that a widower marry his dead wife's sister. This practice mirrors the ancient Israeli custom of 'Levarite marriage,' in which if a man died leaving no sons, his nearest male relative was to marry his widow. While these practices have traditionally applied only to widowed men and women of childbearing age, they do reflect cultural norms involving widowhood and widowerhood and societal expectations of the behavior of widowed persons.

Research Limitations and Future Directions

Although the aging of the population is well documented and widely acknowledged, the implications of old age for the experience of widowhood is, surprisingly, not well recognized. Most studies have focused on younger populations, despite the fact that widowhood is age related and is a characteristic feature of later life, particularly of late old age and especially so for women. Relatively few studies extensively examine issues specific to elderly widowed persons.

Most studies of widowhood do not include comparison groups of those who have not experienced the loss of their spouse, or of those who have experienced other kinds of losses. As a result, conclusions that any observed patterns are, in fact, due exclusively to widowhood may be questionable.

Several recent qualitative studies focus on the narrative accounts of older widowed women and challenge the dominant public narrative of misery and decline, pointing instead to a complexity of experience that is rooted in personal biography and the female life course rather than in later-life widowhood itself.

Although in some countries (such as Canada) social policies have been developed to address issues of particular concern to the widowed (such as income supplementation), few such policies exist worldwide. Where they are present, social programs will need to be as flexible as possible. Today's widowed elderly people have characteristics – in terms of social roles and expectations, availability of family members, labor force history, education, and financial resources – that are quite different from the attributes of the elderly widows and widowers of tomorrow.

See also: Bereavement and Loss; Demography; Life Course; Life Events; Loneliness; Social Networks, Support, and Integration.

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Wisdom

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Glossary

Wisdom – The ideal of human knowledge and character, representing a well-balanced coordination of emotions, motivation, and thought, with good judgment and the ability to offer advice in difficult and uncertain matters of life.

Introduction

Wisdom is a phenomenon characterized by a rich cultural history and complex associations. Across cultures and history, wisdom has been discussed as the ideal of human knowledge and character. Starting from the dictionary definition of wisdom as good judgment and advice in difficult and uncertain matters of life, psychologists have described wisdom as the search for the moderate course between extremes, a dynamic between knowledge and doubt, a sufficient detachment from the problem at hand, and a well-balanced coordination of emotion, motivation, and thought. Within psychological research on wisdom, two kinds of approaches can be distinguished. One is the study of lay conceptions of wisdom, and the other is the attempt to measure behavioral expressions of wisdom. With regard to behavioral expressions, a personal and a general form of wisdom need to be distinguished. Age trajectories and antecedents of general and personal wisdom are discussed.

Historical Background

Since the beginnings of human culture, wisdom has been viewed as the ideal endpoint of human development. Indeed, the idea of wisdom as one of the highest forms of knowledge and skill is evident in the definition of the historical grand master of all scholarship, philosophy: the love/pursuit of wisdom. Historically, wisdom was conceptualized in terms of

a state of idealized being (such as Lady Wisdom), as a process of perfect knowing and judgment, as in King Solomon's judgments, or as an oral or written product such as wisdom-related proverbs and the so-called wisdom literature. Important to recognize is that the identification of wisdom with individuals (such as wise persons), the predominant approach in psychology, is but one of the ways by which wisdom is instantiated. In fact, in the historical literature on wisdom, the identification of wisdom with the mind and character of individuals is not the preferred mode of analysis. Wisdom is considered an ideal that is difficult to be fully represented in the isolated individual.

Throughout history, interest in the topic of wisdom has waxed and waned. In general, two main lines of argument were pivotal in the historical evolution of the concept of wisdom: the distinction between philosophical and practical wisdom – often attributed to Aristotle's differentiation between *sophia* and *phronesis* – and the question of whether wisdom is divine or human. In the Western world, these two issues (philosophical vs. practical; divine vs. human) were at the center of heated discourse during the Renaissance. An initial conclusion of the debate was reached during the later phases of the Enlightenment. Wisdom was still critical, for instance, to the thinking of Kant and Hegel. Both understood wisdom as being based on the coordination of the world of science and the practical world of humankind. However, the eighteenth century French encyclopedia of Diderot (and others), despite its more than 50 volumes, barely mentioned the topic. During the Enlightenment and the process of secularization, wisdom lost its salience as one of the fundamental categories guiding human thought and conduct.

Nevertheless, from time to time, scholars in such fields as philosophy, political science, theology, and cultural anthropology continued to attend to wisdom, although less in a cumulative sense of theory building than in rejuvenating and revisiting its meaning, historical roots, and implications for raising human awareness about the complexities and uncertainties of life. During the past decade, for example, some philosophers have struggled with the definition of wisdom, including the polarization between practical and philosophical wisdom, the integration of different forms of knowledge into one overarching whole, and the search for orientation in life. The latter issue has gained special importance in relation to the advent of postmodernity. Finally, there is the archeological-cultural work dealing with the origins of religious and secular bodies of wisdom-related texts in China, India, Egypt, Old Mesopotamia, and other sites of ancient civilizations. The degree of cultural and historical invariance of wisdom-related proverbs and tales found in this research context is impressive and gives rise to the assumption that concepts such as wisdom, with its related body of knowledge and skills, have been culturally selected because of their adaptive value for humankind.

Among one of the major reasons for the emergence of the psychological study of wisdom in the late 1970s and early 1980s was the search for the potential of aging or, more specifically, the search for domains or types of intellectual functioning that would not show age-related decline. Life experience and wisdom as well as professional expertise, everyday problem solving, or practical intelligence were selected as topics of investigation.

Psychological Approaches to the Definition of Wisdom

A first approach to the definition of wisdom from a psychological perspective is its treatment in dictionaries. The major German historical dictionary, for instance, defined wisdom as "insight and knowledge about oneself and the world … and sound judgment in the case of difficult life problems." Similarly, the *Oxford Dictionary* includes in its definition of wisdom "Good judgment and advice in difficult and uncertain matters of life."

When psychologists approach the definition of wisdom, like philosophers, they are confronted with the need to specify the content and formal properties of wisdom-related thought, judgment, and advice in terms of psychological categories, and also to describe the characteristics of persons who have approached a state of wisdom and who are capable of transmitting wisdom to others. These initial efforts by psychologists for the most part were theoretical and speculative. In his pioneering piece on senescence, G. Stanley Hall, for example, associated wisdom with the emergence of a meditative attitude, philosophic calmness, impartiality, and the desire to draw moral lessons that emerge in later adulthood. Furthermore, other writers have emphasized that wisdom involves the search for the moderate course between extremes, a dynamic between knowledge and doubt, a sufficient detachment from the problem at hand, and a well-balanced coordination of emotion, motivation, and thought. In line with dictionary definitions, writings by psychologists typically refer to wisdom as knowledge about the human condition at its frontier, knowledge about the most difficult questions of the meaning and conduct of life, and

knowledge about the uncertainties of life, about what cannot be known, and how to deal with that limited knowledge.

Implicit (Subjective) Theories about Wisdom

Most empirical research on wisdom in psychology so far has focused on further elaboration of the definition of wisdom. Moving beyond the dictionary definitions of wisdom, research explored the nature of everyday beliefs, folk conceptions, or implicit (subjective) theories of wisdom. The pursuit of answers to questions such as what is wisdom?, how is wisdom different from other forms of intelligence?, which situations require wisdom?, what is a wise act?, and what are the characteristics of wise people? have been at the center of psychological wisdom research during the 1980s. These studies in principle built on research initiated by Clayton and colleagues in 1975, whose methodology to identify lay conceptions of wisdom has become fairly common among wisdom researchers. First, a sample of lay persons or experts (e.g., professors from different fields) are asked to generate a list of wisdom-related characteristics or vignettes. The resulting pool of items – or, at least, a subgroup of items that is left after terms have been screened for synonyms and redundancies – in turn, is rated by another group of individuals in terms of its wisdom-relatedness or -typicality. Subsequently, factor analytical procedures are frequently used to identify underlying dimensions of items. In Clayton and Birren's study, this procedure yielded three dimensions found to be prototypical of wise people: (1) affective characteristics such as empathy and compassion, (2) reflective processes such as intuition and introspection, and (3) cognitive capacities such as experience and intelligence. The dimensions found by Clayton and Birren still pertain today. Recently, new dimensions have been added, and characteristics have been ordered differently (see **Table 1**). For example, Bluck and Glück in their review of implicit measures drew more heavily on the distinction between real-world skills and interpersonal skills (concern for others) as opposed to capacities with a less interactive emphasis, such as cognitive ability, insight, and reflective attitude. Furthermore, results of studies on implicit notions of wisdom are heavily influenced by the initial pool of items. For example, a study by Hershey and Farrell, comprising also characteristics assumed not to be associated with wisdom, yielded one dimension labeled egotism comprising only attributes deemed as unwise. In the same vein, another study including items referring to protection of the environment or religion resulted in two additional factors that had not been identified by previous studies (see **Table 1**).

Additional dimensions of a contextual and interactive nature emerge when individuals are asked about their own experiences with wisdom (rather than describing a wise person in general), as is the case, for example, in studies on wisdom nominees. In these studies, typically, individuals are asked to name persons they consider as being wise, and potential commonalities are identified among the nominees. The most general finding of these studies is that most wisdom nominees are relatively old (i.e., around 60 years). Further criteria ascribed to wise people emerging from the nominee approach – next to those mentioned previously – were, most commonly, guidance and moral principles.

Finally one may ask the question, what is the purpose of wisdom in everyday life? Drawing on autobiographical memories and structured interviews, three forms of wisdom were identified: empathy and support, self-determination and assertion, and knowledge and flexibility. Self-determination and assertion, as opposed to the other two facets, may be recognized as an aspect of wisdom primarily when people are asked about their own life, that is, when interviewees have also access to their inner thoughts, feelings, and motivations. A similar result, that is, a focus on inner motives or the relationship between intentions and external circumstances, was found when analyzing wise acts. According to studies by Oser and colleagues, wise acts seem to be characterized by the following seven features: (1) paradoxical, unexpected; (2) morally upright; (3) selfless; (4) overcoming internal and external dictates; (5) striving toward equilibrium; (6) implying a risk; (7) striving toward improving the human condition. Hence, different approaches to the study of implicit notions of wisdom yield findings that supplement and enrich the results from other studies.

From this research on implicit theories of wisdom and wise persons, it is evident that people in Western samples hold fairly clear-cut images of the nature of wisdom. What about other cultures? Do similar conceptions of wisdom arise when investigating participants in non-Western cultures? Along these lines, Takahashi and Bordia compared implicit definitions of wisdom among young adults from the United States, Australia, India, and Japan. They interpreted their findings to mean that the association between wisdom and cognitive variables pervasive to findings collected in Western samples is perceived as less important in East Asian cultures, in which characteristics such as aged, experienced, and discreet are perceived as pivotal for wisdom. Additionally, the

Table 1 Implicit theories of wisdom: a comparison of findings from five studies with sample items[a]

Clayton (1976)	*Sternberg (1986)*	*Holliday and Chandler (1986)*	*Hershey and Farrell (1997)*	*Jason et al. (2001)*
Affective (1) Empathy Compassion	Sagacity (2) Concern for others Considers advice Perspicacity (6) Intuition Offers right and true solutions	Interpersonal skills (4) Sensitive Sociable Judgment and communication skills (2) Is a good source of advice Understands life	Egotism, inverse (2) Extravagant Presumptuous Perceptive judgment (1) Sincere Fair Thoughtful	Warmth (2) Compassion and warmth for others Kindness
Reflective (2) Intuition Introspection	Judgment (4) Acts within own limitations Is sensible	Social unobtrusiveness (5) Discreet Non-judgmental	Basic temperament (3) Withdrawn Reflective	Harmony (1) Good judgment Experiences an underlying unity in life
	Learning from ideas and environment (3) Perceptive Learns from mistakes	Exceptional understanding as based on ordinary experience (1) Has learned from experience Sees things in a larger context		
Cognitive (3) Experience Intelligence	Reasoning ability (1) Good problem-solving ability Logical mind Expeditious use of information (5) Experienced Seeks out information	General competence (3) Intelligent Educated		Intelligence (3) Intelligence Problem-solving ability
				Connecting to nature (4) Reverence for nature Childlike wonder and awe Spirituality (5) Feels love, fellowship, or union with god Living a spiritual life

Modified from Staudinger UM and Baltes PB (1994) Psychology of wisdom. In: Sternberg RJ (ed.) *Encyclopedia of Human Intelligence*, Vol. 2, pp. 1143–1152. New York: MacMillan.

[a] Sequence of factors or dimensions obtained in original research is given in parentheses. Studies are based on different methodologies (factor analysis, multidimensional scaling).

association of wisdom with experience and practical knowledge was found to be stronger in Asian than in Western samples.

When summarizing findings on how people across different cultures view wisdom, wise people, and wise acts, five findings seem especially noteworthy. First, in the minds of people, wisdom seems to be closely related to wise persons and their acts as carriers of wisdom. Second, wise people are expected to combine features of mind and character and to balance multiple interests and choices. Third, wisdom carries a very strong interpersonal and social aspect with regard both to its application (advice) and the consensual recognition of its occurrence. Fourth, wisdom exhibits overlap with other related concepts, such as intelligence, but in aspects like sagacity, prudence, and the integration of cognition, emotion, and motivation, it also carries unique variance. Fifth, it seems to make a difference whether one conceives of one's own wisdom or describes that of another prototypical person.

Explicit Theories and the Assessment of Wisdom

A more recent line of empirical psychological inquiry on wisdom addresses the question of how to measure

behavioral expressions of wisdom. Although wisdom frequently is considered to defy any attempts of scientific identification, research on explicit theories of wisdom has shown that it is possible to measure wisdom in terms of personality characteristics (standardized or open-ended), characteristics of adult thought, and performance (judgment, advice) on difficult life tasks.

The various lines of work can be subsumed under two main headings, namely, personal wisdom and general wisdom. This distinction is loosely related to the philosophical separation between the ontology of the first and the third person. The ontology of the first person indicates insight into life based on personal experience. In contrast, the ontology of the third person refers to the view of life that is based on an observer's perspective. In loose analogy to Searle's first-person perspective, personal wisdom refers to a person's insight into his or her own life: what does a person know about him- or herself, his or her life? Analogous to the third-person perspective, general wisdom is concerned with insights into life in general. What does an individual know about life from an observer's point of view, that is, when she or he is not personally concerned? For instance, your general wisdom is tapped if a friend comes to you because his or her marriage is in a deep crisis and he or she is considering divorce. But it takes your personal wisdom if you are searching for a solution because your own marriage is in a deep crisis and you are considering divorce.

The distinction between personal and general wisdom might be helpful when trying to settle some of the ongoing debates in the field of wisdom research. For heuristic purposes, **Table 2** assigns many of the extant approaches in research on wisdom to either a personal wisdom or a general wisdom perspective. Note that this categorization is sometimes difficult to make because the original authors do not describe their notion of wisdom along the distinction between personal and general wisdom. Consequently, the assignment is based on inferences on the authors' behalf and is made according to the relative emphasis placed on either personal or general wisdom.

The two types of wisdom are usually related to different research traditions. The approaches primarily geared toward personal wisdom are usually based in the tradition of personality research and personality development. Wisdom in this perspective describes the mature personality or the endpoint of personality growth (e.g., Erikson or Ryff). Thinking about wisdom from this vantage point clearly reveals a close link to research on coping. The approaches primarily investigating general wisdom typically have a stronger connection with the historical wisdom literature (i.e., wisdom as sound advice) and an expertise approach to the study of wisdom (e.g., Berlin wisdom paradigm, Sternberg's balance theory of wisdom).

Table 2 Tentative assignment of extant wisdom approaches to personal or general wisdom[a]

Wisdom approach	*Personal wisdom*	*General wisdom*
Explicit theories		
Personality perspective		
Erikson	X	
Loevinger	X	
Helson and Wink	X	
Labouvie-Vief	X	
Ardelt	X	
Webster	X	
Orwoll and Perlmutter	X	
Neopiagetian perspective, e.g., Arlin, Kitchener, Kramer		X
Expertise perspective		
Berlin paradigm		X
Sternberg		X
Implicit theories		
Holliday and Chandler		X
Clayton and Birren		X
Hershey and Farrell		X
Jason et al.		X

[a] Modified with permission from Staudinger UM, Dörner J, and Mickler C (2005) Wisdom and personality. In: Sternberg RJ and Jordan J (eds.) *A Handbook of Wisdom. Psychological Perspectives*, pp. 191–219. New York: Cambridge University Press.

The distinction between personal and general wisdom also is relevant when exploring the ontogenesis of wisdom. First, there is reason to assume that it is the dynamic between personal and general life insight that is at the heart of eventually attaining wisdom. Decades of research on self-regulation as well as research on the therapeutical process have demonstrated that it is much more difficult to obtain insight into one's own life than into the difficulties and problems of others. Thus, general wisdom might be less difficult to attain than personal wisdom, and therefore the final attainment of the former may precede that of the latter in ontogenesis. Certainly, in the course of ontogeny, that is, in working toward general and/or personal wisdom, both types may alternate in taking the lead. We do know, however, from research on the development of the self-concept that the infant appropriates general knowledge about the world before she or he is able to acknowledge the self. From research on the self later in ontogeny, we have learned that self-related information is processed differently than general information, showing, for example, in a biased processing of

self-referent information, which indeed may hinder the development of personal wisdom. Furthermore, it is conceivable that individuals who have attained personal wisdom do not have the ability and/or the motivation to think about life problems beyond their own specific circumstances or are lacking the ability to give advice. As a consequence, we expect that finding both personal and general wisdom in one person is a very rare event. As a prerequesite, however, to test the coincidence and different trajectories of the two types of wisdom, they need to be conceptualized and measured independently of each other.

Approaches to General Wisdom

Various approaches to general wisdom can be distinguished, one of which is the cultural-historical analysis of wisdom mentioned previously. Cultural-historical work concerning the origins of religious and secular bodies of wisdom-related texts has revealed a common core of defining features of wisdom that seems to reflect the notion of general wisdom more than that of personal wisdom. According to this analysis conducted by Paul Baltes, the common core of wisdom is the following: (1) wisdom comprises knowledge with extraordinary scope, depth, measure, and balance; (2) it addresses important and difficult questions and strategies about the conduct and meaning of life; (3) it includes knowledge about the limits of knowledge and the uncertainties of the world; (4) it represents a truly superior level of knowledge, judgment, and advice; and (5) it is easily recognized when manifested, though difficult to achieve and to specify. Note that in this analysis personality characteristics are not mentioned as a defining feature common to wisdom across cultures and historical time.

Within psychology, different approaches to general wisdom are distinguished, such as wisdom as postformal thought in the Neopiagetian tradition, Sternberg's balance theory of wisdom, and the notion of wisdom as expert knowledge in the Berlin wisdom paradigm. In the following, these conceptions of wisdom are discussed in more detail.

Informed by the Piagetian tradition of studying cognitive development, several investigators have proposed a postformal stage of adult thinking and related this stage to mature thought or wisdom. In theories of postformal thought, wisdom is conceptualized as increasingly complex and dialectic thinking. Criteria of postformal thinking include awareness of multiple causes and solutions, awareness of paradoxes and contradictions, and the ability to deal with uncertainty, inconsistency, imperfection, and compromise. Pivotal for postformal thinking is the transcendence of the universal truth criterion that characterizes formal logic – a tolerance of ambiguity created by an acceptance of multiple truths. In this approach, little attention has been paid to the need for bounded relativity.

Empirical research in the field of Neopiagetian conceptions of wisdom has addressed, for example, the relationship of postformal stages of development with social cognition. For example, postformal thinkers demonstrated a tendency to show less of an actor-observer effect (i.e., situational causes are held responsible for one's own behavior and dispositional factors for others' behavior) and higher levels of moral reasoning than non-postformal thinkers. It was also found that positive mood induction and relaxation improved postformal operations, whereas focusing attention had detrimental effects. In sum, it might be concluded that wise thinking in the Neopiagetian sense is related to a tolerant and open-minded attitude, which is also characteristic of one of the big five personality dimensions, that is, openness to experience. Plus, it seems easier to think wisely when being relaxed and in a positive mood.

In Sternberg's approach, wisdom is related to both practical and academic intelligence. Academic intelligence provides a necessary but by no means sufficient basis to wisdom-related functioning. But wisdom also involves the application of tacit knowledge, which is the key aspect of practical intelligence. Tacit knowledge is action-oriented (procedural) knowledge that is usually acquired without direct help from others (rather by role modeling) and that allows individuals to achieve goals that they personally value. In contrast to practical intelligence, however, wisdom by definition is oriented toward a balance between self-interest, the interests of others, and other contextual interests to achieve a common good. This balancing is the key aspect of Sternberg's theory of wisdom. The output of wisdom typically is a piece of advice. Wisdom is assessed by presenting people with problems that involve solutions that maximize a variety of intrapersonal, interpersonal, and extrapersonal interests.

A wise person in this sense is comfortable with ambiguity, in contrast to a conventionally intelligent person, who considers ambiguity as something to be resolved, and in contrast to a creative person, who can tolerate ambiguity but is uncomfortable with it. Also, when managing obstacles, the wise person tries to understand the problem and its implications for self and others. The wise person endorses a judicial thinking style, that is, she or he always

tries to understand why, rather than judging whether something is good or bad. Also related to the area of personality is the assumption that a wise person is highly motivated to seek the common good.

In the Berlin wisdom paradigm, wisdom is defined as expertise in the fundamental pragmatics of life. The fundamental pragmatics of life refer to deep knowledge and sound judgment about the essence of the human condition and the ways and means of planning, managing, and understanding a good life. Expert knowledge in fundamental pragmatics of life can be described according to five criteria. The first criterion, factual knowledge, concerns knowledge about such topics as human nature, life span development, variations in developmental processes and outcomes, interpersonal relations, and social norms. The second criterion, procedural knowledge, involves strategies and heuristics for dealing with the meaning and conduct of life, for example, heuristics for giving advice and ways to handle life conflicts. Additionally, a wise person should show life span contextualism, that is, consider life problems in relation to the domains of life (e.g., education, family, work, friends, leisure, the public good of society) and their interrelations and to put these in a lifetime perspective (i.e., past, present, future). Relativism of values and life priorities is another criterion of wisdom. This means to acknowledge and tolerate interindividual differences in values, as long as they are geared toward optimizing and balancing the individual and the common good. The last criterion, the recognition and management of uncertainty, is based on the idea that human beings can never know everything that is necessary to determine the best decision in the present, to perfectly predict the future, or to be 100% sure about why things happened the way they did in the past. A wise person is aware of this uncertainty and has developed ways to manage it.

To elicit and measure wisdom-related knowledge and skills, the Berlin group of wisdom researchers has presented participants with difficult life dilemmas such as the following: imagine a good friend of yours calls you up and tells you that she can't go on anymore and has decided to commit suicide. What would you be thinking about, how would you deal with this situation? Participants are then asked to think aloud about the dilemma. Their responses are recorded on tape and later transcribed. To quantify performance quality, a select panel of judges, who are extensively trained and calibrated, evaluates the protocols of the respondents in light of the five wisdom-related criteria using seven-point scales. The obtained scores are reliable and provide an approximation of the quantity and quality of wisdom-related knowledge and skills of a given person. When using this wisdom paradigm to study people who were nominated as wise according to nominators' subjective beliefs about wisdom, wisdom nominees received higher wisdom scores than comparable control samples of various ages and professional backgrounds.

Part of the Berlin paradigm also is a general framework outlining the conditions for the development of wisdom as it is instantiated in persons. The model presents a set of factors and processes that need to cooperate for wisdom to develop. First, there are general individual characteristics, such as intelligence and personality. Second, the model presumes that the development of wisdom is advanced by certain expertise-specific factors, such as a strong motivation to find out about life, practice with difficult life situations, and being guided by a mentor. Third, the model implies the operation of macro-level facilitative experiential contexts. For instance, certain professions and historical periods are more facilitative than others. Further, certain social-cognitive processes (life planning, life management, and life review) are assumed to be critical for the development of wisdom-related knowledge and judgment.

The empirical work based on this ontogenetic model and the measurement paradigm produced outcomes consistent with expectations. Contrary to work on the fluid mechanics of cognitive aging, older adults perform as well as younger adults. It seems that wisdom-related knowledge and judgment emerges between the ages of 14 and 25 years. Furthermore, when age has been combined with wisdom-related experiential contexts, such as professional specialization specifically involving training and experience in matters of life (e.g., clinical psychology), higher levels of performance were observed. In line with the historical wisdom literature, which portrays wisdom as the ideal combination of mind and virtue, it was found that wisdom-related performance is best predicted by measures located at the interface of cognition and personality, such as a judicious cognitive style, creativity, and moral reasoning. Neither intelligence nor personality independently of each other made a significant contribution to wisdom-related knowledge and judgment. When it comes to emotional experiences, general wisdom as measured according to the Berlin wisdom paradigm has been shown to be negatively related to both positive (e.g., happy, cheerful) and negative affect (e.g., angry, afraid) but positively with affective involvement (e.g., interested, inspired). This relational pattern suggests that wisdom might go along with a more realistic, less self-enhancing, and less positively biased view on life but at the same time

with better skills of coping with negative emotions. Furthermore, in line with implicit notions of wisdom, wisdom-related performance is positively related to the endorsement of values referring to personal growth, life insight, societal engagement, the well-being of friends, and ecological protection. Wisdom-related knowledge and judgment have also been found to demonstrate plasticity. In two intervention studies, Staudinger and co-workers found that either by providing for a certain type of social performance context or by teaching a specific knowledge search strategy, wisdom-related performance was significantly increased.

Approaches to Personal wisdom

When we turn from conceptions of general wisdom to those of personal wisdom, two other notions come to mind: maturity and personal growth. Influential conceptions of personal wisdom can be found in clinical, personality, and developmental psychology. However, only a selection can be discussed here, namely, some approaches in the tradition of wisdom as a personality characteristic (e.g., Webster), Loevinger's concept of ego development, and Labouvie-Vief's dichotomy of affect complexity and affect optimization, along with a conception of personal wisdom that has been designed in analogy to the Berlin wisdom paradigm and an operationalization of personality growth that is based on the maturity of the self-concept.

In the attempt to capture the characteristics of wise persons rather than those of wise thought and knowledge, Webster developed the self-assessment wisdom scale (SAWS), which assesses five dimensions of wise individuals: emotional regulation, reminiscence and reflectiveness, openness to experience, humor, and experience. In line with expectations, the SAWS scores have been shown to correlate with measures of generativity and ego integrity. Furthermore, no significant age differences were found. Preliminary evidence on the convergent validity of the SAWS seems to indicate that the scale measures something like personal wisdom. However, it remains unclear whether these predictive relationships are mediated by standard measures of personality and intelligence and to which degree the results of the SAWS are distorted by social desirability.

It was Loevinger's ambition to capture character development in a stage model following the Piagetian model of cognitive development. Loevinger conceived the stages of ego development as a successive progression toward psychological maturity, unfolding along the four dimensions of impulse control, interpersonal style, conscious preoccupations, and cognitive styles. The model comprises eight stages (impulsive, self-protective, conformist, self-aware, conscientious, individualistic, autonomous, integrated) that are characterized by increasingly mature forms of those four dimensions. Most people are categorized to be in the third to fifth stages, that is the conformist, self-aware, and conscientious stages. The eighth stage, the integrated stage, is rarely observed in random samples. Ego development is measured by a sentence completion task.

With regard to predictive validity, ego level has been found to be positively related with ego resiliency, interpersonal integrity, and regulation of needs, or mastery of socioemotional tasks and impulse control, as well as indicators of mental health. Interestingly, ego level is also positively correlated with number of lifetime psychiatric visits and regular psychotherapeutic sessions. It is unclear, however, whether psychotherapy helped subjects to advance developmentally or whether later-stage capacity to see ambiguities in life increased their willingness to seek psychotherapy. The latter interpretation is in line with the positive quadratic relation between neuroticism and ego level (i.e., higher neuroticism at low and high ego levels) and a negative quadratic relation between conscientiousness and ego level (i.e., lower conscientiousness at low and high ego levels). Openness to experience, extraversion, and agreeableness show positive linear relations with ego level. Finally, chronological age is unrelated to ego development.

In sum, this pattern of results revolving around Loevinger's measure of ego development suggests that moving beyond the given, seeing reality more clearly, and transcending extant social norms, central features of wisdom, do not come without costs. It seems that being faced with the complexities of one's own life in the way it is true for a person at high levels of ego development does not always lead to greater happiness but also to greater concern and doubt, as well as to the insight that further self-development is needed (I know that I don't know).

Combining the cognitive theory of Piaget with psychoanalytic notions and ideas from adult attachment theory, Labouvie-Vief designed developmental models of self as well as emotional understanding. Building on this earlier work, Gisela Labouvie-Vief in her most recent publications has focused on the development and/or maturation of self- and affect regulation. In this latest approach, she has developed a notion of growth or maturity that combines affect optimization (AO), "the tendency to constrain affect to positive values," with affect complexity (AC), "the amplification of affect in the search for

differentiation and objectivity" (Lebouvie-Vief and Medler 2002:571). In this notion of maturity, it is crucial that the search for complexity and differentiation is combined with or better constrained by a search for optimizing positive affect in any given situation. At the same time, the search for positive affect is guarded by the ability to experience events and other persons in an open and differentiated fashion. Combining the two (dichotomized) dimensions of AC and AO results in four personality types.

Labouvie-Vief and Medler could show that these four types are related in a predictable and systematic manner to a variety of indicators of psychological functioning and chronological age. For example, those with high levels on both AC and AO are characterized by high ego levels, high intelligence, and adaptive coping patterns, excluding repressive or regressive strategies. In contrast, across the different indicators, such as intelligence, affect regulation, coping, and personality, those individuals with low levels on both dimensions demonstrate the lowest levels of functioning.

Another method to measure personal wisdom has been developed along the lines of the Berlin general wisdom paradigm. Five criteria have been defined to index personal wisdom that are based on the literature on personality development. The first criterion is rich self-knowledge, that is, deep insight into oneself. A self-wise person should be aware of his or her own competencies, emotions, and goals and have a sense of meaning in life. The second criterion requires of a self-wise person to have available heuristics for growth and self-regulation (e.g., how to express and regulate emotions or how to develop and maintain deep social relations). Humor is an example of an important heuristic that helps one cope with various difficult and challenging situations. Interrelating the self, the third criterion, refers to the ability to reflect on and have insight into the possible causes of one's behavior and/or feelings. The fourth criterion is called self-relativism. People high in self-relativism are able to evaluate themselves as well as others with a distanced view. They critically appraise their own behavior but at the same time display a basic acceptance of themselves. They also show tolerance for others' values and lifestyles – as long as they are not damaging to self or others. Finally, tolerance of ambiguity involves the ability to recognize and manage the uncertainties in one's own life and one's own development. Personal wisdom is measured by first using a thinking-aloud and subsequently a rating procedure.

In a first study, the new measure of personal wisdom showed good convergent validity. It was positively correlated with other measures of personality growth, such as Ryff's personal growth and purpose in life and Loevinger's ego development, as well as with benevolent values. With regard to discriminant validity, it was demonstrated that personal wisdom, as to be expected for a measure of personal maturity, was uncorrelated with notions of well-being and adjustment, such as life satisfaction, negative or positive emotions, and adaptive motives such as power, achievement, and hedonism. Also, personal wisdom is not preempted by knowing a person's intelligence. As far as the relationship with personality variables is concerned, openness to experience was the most important predictor – of the other big five variables, none showed significant correlations with personal wisdom. Psychological mindedness, a concept measuring interest in thoughts and feelings of other people, however, was positively correlated with personal wisdom.

As a theoretical background for the construction of yet another measure of personal wisdom, the literature on the self-concept as well as on personality growth was reviewed. Five self-concept facets were identified as theoretically meaningful indicators of personal wisdom, namely, complexity of content, self-concept integration, affect balance, self-esteem, and value orientation. It was hypothesized that only by combining these five components could one arrive at an appropriate operationalization of personal wisdom. That is, a profile of the five self-concept facets was established that should serve as a prototype of a mature personality as reflected in the self-concept or self-concept maturity (SCM). As hypothesized, SCM correlated strongly and significantly with other measures of personal wisdom, especially with Loevinger's ego development and the newly developed personal wisdom task presented previously, whereas no significant associations existed with chronological age.

Conclusion and Future Directions

The concept of wisdom represents a fruitful topic for psychological research: the study of wisdom emphasizes the search for continued optimization and the further evolution of the human condition, and in a prototypical fashion, it allows for the study of collaboration between cognitive, emotional, and motivational processes. We expect that future research on wisdom will be expanded in at least three ways: (1) the further identification of social and personality factors and life processes relevant for the ontogeny of wisdom, (2) the exploration of wisdom as a meta-heuristic aimed at orchestrating mind and

virtue toward human excellence, and (3) the differentiation between personal and general wisdom outlined in this article might contribute to building a psychological art of life.

See also: Emotions; Intelligence.

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Work and Employment: Individual

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Glossary

Age Discrimination in Employment Act (ADEA) – US Congressional legislation passed in 1967 and amended in 1978 and 1986 that protects workers age 40 years and older from unfair discrimination at work.

Age Stereotypes – Generalized beliefs about the characteristics of older people.

Downsizing – The systematic reduction of employees and possibly occupational areas within an organization.

Equal Employment Opportunity Commission (EEOC) – A regulatory agency with the responsibility of enforcing discrimination laws concerning the workplace.

Functional Age – Performance-based measures of age that are based on the premise that there is great individual variability in abilities and functioning at all ages.

Psychosocial Age – Measures of age based on social perceptions of the individual including perceptions of the characteristics of the individual and self-perceptions of age.

Introduction

Today's workforce differs substantially from that of the past. The workforce is more diverse, with more women, more ethnic and racial representation, and more older workers. In the United States, as in other

countries, four forces combine to cause an aging workforce. First, there are a large number of older employees in society and in the workplace reflecting the baby boomer generation. Second, the incoming generation of younger work cohorts (labeled the baby bust generation) is few in number. Third, the proportion of older workers delaying retirement has been increasing since the mid-1990s due to a loss of retirement security and mandatory retirement age. Finally, due to an increase in concerns about age discrimination, especially within the United States, more organizations focus on retraining and retaining older workers rather than trying to outsource them.

Researchers increasingly have investigated the relationships among worker age and important work processes and outcomes, including unemployment, hiring, performance appraisal, work attitudes, career characteristics, turnover, absence and terminations, and discrimination. This article examines issues concerning older workers as they seek employment, secure employment within the organization, work within the organization, and exit the paid employment domain. Before these employment issues are explored, however, a brief discussion is presented on the meaning and measurement of age in work-related research. This discussion is important because the information accumulated on older workers is based on research using chronological age, yet chronological age is only one assessment of how 'old' a person is. Finally, the article presents a brief overview of the theoretical developments in this area.

Conceptions of Age

The study of aging and work, specifically, industrial gerontology, examines issues concerning the employment and retirement of middle-aged and older workers. A continuing problem in the field of industrial gerontology is the lack of an agreed-upon definition for mature and older workers. One reason for the difficulty in securing an adequate definition is that aging is a multidimensional process that is difficult to embrace in a single definition or measure. This section discusses four approaches to defining the older worker's age: (1) chronological or legal, (2) functional, (3) psychosocial, and (4) organizational. It is important to keep in mind, however, that each of these approaches to conceptualizing age can be categorized into two general groups: person-based measures and context-based measures of age. Person-based measures focus chiefly on the age characteristics of the individual, whereas context-based measures incorporate aspects of the work situation and often reflect comparisons among persons in the situation.

Chronological or Legal Age

Chronological or legal age is the most widely used person-based measure in research on older workers. The US Age Discrimination in Employment Act (ADEA) of 1967 and amended in 1978 and 1986 protects workers over the age of 40, reflecting the fact that job openings may be disproportionately barred to applicants 40–45 years, and more so for applicants over 55. Two individuals with the same chronological age may vary in terms of the subjective meaning that age has for them. For example, an individual's interpretation of his or her age may reflect perceptions of health, appearance, energy, and so forth.

Functional Age

Another largely person-based age measure is functional age. Functional age is a performance-based definition of age that is based on the premise that there is great individual variation in abilities and functioning at all ages. As chronological age increases, individuals change both biologically and psychologically, including declines in abilities and increases in experience and judgment. The concept of functional age has been criticized on a number of grounds, with a major limitation being the use of a single index and the assumption of decline with increasing chronological years. Even when there are measurable age-related functional changes, these changes may not translate to performance decrements in any particular job.

Psychosocial and Organizational

Psychosocial definitions of older workers are based on social perceptions of the individual, including stereotypic perceptions of older workers and self-perceptions of age. These perceptions may depend in part on the age type of the job that one holds or the age composition of the work group. These approaches are discussed together because both include largely context-based definitions of age; they vary perhaps in terms of unit of focus (i.e., the psychosocial approach is a more individual unit of analysis, whereas the organizational approach may use the group or organization as the unit of analysis).

Industrial gerontologists have suggested that the older worker should be examined in relation to the work context. The work context includes characteristics of the group, age perceptions of self compared to work group members, age perceptions of self compared to one's supervisor, and age perceptions of self compared with typical ages within a given occupation or career path.

There is evidence that context-bound measures of age can predict such work outcomes as self- and manager-rated performance, manager-rated promotability, perceptions of organizational support, and self- and manager-rated on-the-job training. Furthermore, differences in the ages of supervisors and subordinates have been used to predict work outcomes. The similarity-attraction model has been used to conceptualize the impact of differences in age between the supervisor and the subordinate. Although empirical studies provide little support for this paradigm (e.g., similarity of supervisor and subordinate age had no effect on performance ratings, manager's liking of the subordinate, employee attitudes, or propensity to quit), others have argued that age differences between the supervisor and subordinate are most important when they defy social norms (e.g., when the subordinate is older than the manager). Furthermore, support for age as defined by the specific organizational context has been found in research on age norms. For example, performance ratings are higher for managers who are viewed as younger than the perceived typical ages of individuals at that career stage and lower for managers who are seen as older than the 'norm' for that career stage. In general, men who are 'behind schedule' (older than the norm) with respect to schooling, marriage, and job entry are more likely to have lower overall career earnings than men who are on schedule (or similar to the normative age group).

The key factor to keep in mind when defining older workers is that they are often people who are substantially younger than the subjects in more typical gerontological research. Typically, older workers include individuals who are 45, 50, 60, 65, or perhaps 70 years old. In gerontological research, 'older' populations might be 80–100 years old, and are likely to have been out of the workforce for several decades. Therefore, in the discussion of age and work outcomes, employees that might be considered older can range from 40 to over 75 years old.

Entry into Employment

Job Search and Unemployment

During 2002 in the United States, there were approximately 17 700 layoffs, which resulted in almost 2 million claims for unemployment compensation insurance. Although more individuals between 25 and 45 years were unemployed, the average length of time of unemployment was longer for older individuals than for younger individuals (mean = 18 weeks for those over 54 and 12.7 weeks for 25- to 34-year-olds). Little research has been done on job search behaviors of older workers. It is generally assumed that older workers are less likely than younger workers to search for alternative employment if they are presently employed. This is consistent with research showing lower turnover intentions for older workers. Age is viewed as one factor affecting marketability, which influences a candidate's likelihood of seeking jobs. Interestingly, recent research on employed managers showed that age had little impact on job search behavior, whereas job satisfaction, compensation, and perceptions of organizational success were negatively related to job search behavior. This suggests that it is working conditions, not age, that influences job search behavior. Furthermore, research suggests that age does not influence the type of recruitment sources used. Both young and old people are most likely to use newspaper ads.

Hiring and Selection Practices

Research investigating the impact of age on hiring decisions has chiefly focused on issues pertaining to discrimination. Of particular interest is when and if older workers are discriminated against in hiring. Research findings have been quite varied, perhaps due in part to the nature of the samples employed. Meta-analyses of laboratory studies on age and selection show no significant age effects when raters evaluated either a younger or an older applicant. However, when raters evaluated both a younger and an older applicant, younger applicants were rated as more qualified.

Simulation studies using actual workers have also produced varied results. One study showed that young applicants were recommended for hire more often than old applicants. Other studies suggest that factors such as competence and job status moderated age effects; qualified older applicants fare well in high-status jobs.

Studies of actual hire decisions have also shown inconsistent results. One study showed that older applicants received lower hiring recommendations and were rated lower in intelligence than younger applicants. A second study showed that age correlates positively with interview scores, suggesting that older applicants were preferred over younger applicants. However, the latter sample was fairly young (most applicants ranged from 21 to 30 years old), raising questions of generalizability. A final study examined similarity in age between the interviewer and applicant and found that age similarity had no impact on the interview outcome.

All three types of subject samples reviewed showed mixed results in terms of age bias in hiring decisions. A number of possibilities emerge to explain the mixed

findings. First, student subjects and working subjects react somewhat differently to older and younger applicants, particularly in relation to jobs of varying status. This may be due to the differences in the ages of subjects, or difference in work experience. Second, several studies showing age bias had subjects compare old and young applicants with identical qualifications. The design of these studies may actually contribute to age bias effects because subjects may assume that a young person with equal qualifications to an older person is more competent, having reached the same skill level at a younger age. A third possibility is that characteristics of the job in terms of age stereotyping may be at work. A number of studies suggest that jobs are typed in terms of whether they are appropriate for young, middle-aged, or older workers. This age typing in turn affects the treatment of older workers. However, this issue has not been systematically investigated in prior studies of hiring. Finally, the age composition of the applicant pool appears to have an impact on the hiring process, such that older workers are more likely to be hired when other older workers are already in the applicant pool.

Experiences in Organizations

Age and Job Performance

Considerable research in both lab and field settings indicates that job performance does not decline with age. However, there are a number of issues to consider in this research. The first is the definition of the domain of performance. Performance measures used in this research include supervisory ratings, productivity indices and other objective measures (e.g., sales volume), turnover, and absenteeism. There is some indication that the age–performance relationship varies with the type of performance measure used. Further, in recent meta-analyses, a number of problems have been identified with research linking age and job performance, including the following: (1) few studies include workers older than 60 years of age; (2) research designs are cross-sectional; (3) longitudinal research suggests a non-linear relationship with age; (4) age–performance relationships are influenced by occupation; and (5) there are relatively few studies and these often have small sample sizes.

Physical capacity, which refers to outcomes of coordinated activity among major components of the motor system involved in carrying out work, begins to show a decline in middle age. Declines are most noticeable in tasks involving perceptual or psychomotor speed. However, each individual will experience performance declines at different ages, and most often these declines are gradual. Declines in physical capacity should be examined on an individual basis, because they may not translate into any perceptible interference with the essential activities of the job (*see* Motor Control; Perception).

Any modest relationship found between age and performance may be better understood as a relationship between job knowledge and job performance. Some industrial and organizational psychologists have suggested that job incumbents acquire most of the job knowledge needed for successful performance during the first several years on the job. Individual differences in job experience may be associated with significant differences in job performance, especially during the first few years. After a while, however, job experience makes diminishing contributions to job knowledge and thus job performance. Small differences in job experience among younger workers may translate into large differences in job knowledge and job performance. Therefore, among younger workers, age differences will be related to differences in job performance; but as additional job experience contributes little incremental job knowledge, the amount of new job knowledge gained each year becomes less and less such that, overall, age has a weak relationship with job knowledge and little or no relationship with job performance.

Laboratory studies of task performance and age have shown age-related sensory deficits across a wide range of psychological functions, including peripheral and motor mechanisms, memory, and information processing. With complex or demanding tasks, such as in multisource monitoring, older people tend to be particularly disadvantaged. Although it might be expected that older individuals would perform less well on more complicated real-world tasks, the assessment of age effects in occupational settings involves considerable methodological problems. These methodological deficiencies include a lack of reliability and comparability of performance measures across age groups, selective attrition of subjects with healthier ones surviving, and selection biases (*see* Attention; Memory).

Accidents Although research results are mixed, the most common finding is that accident rates are lower among older workers compared to workers aged 24 and 25 to 44 years. However, research has also found a positive age–accident relationship, as well as an inverted-U, U-shaped, or non-significant age–accident relationship. Moderators of this relationship include sex and type of occupation. Accident rates are generally lower for women and higher for blue-collar work (blue-collar jobs account for 70% of all injuries and are eight times riskier than white-collar occupations). Older employees who occupy

jobs normally held by younger workers incurred more accidents than their younger counterparts.

Although older workers may experience lower rates of injury, they generally lose more time per injury than younger workers. The severity of injury may increase with age and may require a longer time to recover. An injury is also more likely to result in a permanent disability for older employees. Deaths due to accidents also increase with age.

Absenteeism

Absenteeism is one form of withdrawal behavior (turnover is the other) that can be costly both to the organization and to individuals. Meta-analyses of the relationship between age and absenteeism showed significant results that depended upon the type of absence measure used. Absence frequency is a measure of avoidable absence, whereas absence duration is a measure of unavoidable absence. Absence frequency is negatively related to employee age; research findings for unavoidable absences are mixed. Recent research suggests that employee age interacts with employee sex for both avoidable and unavoidable absenteeism behavior. Females show a stronger negative relationship between age and time lost than males, whereas males show a negative relationship between age and frequency of absences and females show a positive relationship. Older female employees are more likely to have frequent absences, but are less likely to have a number of consecutive days absent from the workplace compared to male employees. Although multifactor models have been proposed and tested for understanding absenteeism, age itself is thought to be a weak predictor of attendance. Furthermore, with increasing numbers of women in the workforce, career, dual-career, and family issues need to be considered and incorporated into these models.

Age and Training

As the average age of workers increases, the issue of training older workers becomes more important. Research suggests that the relationship between age and success in training depends on both the context of training and the specific criteria used to define success. Age has the greatest influence when the content is novel (e.g., computer use) and the criterion for success is speed in completing training.

Several decades of research on the effectiveness of training interventions with workers of various ages have been carried out. Older workers learn less quickly than their younger counterparts. However, if work procedures remain unchanged for long periods of time, the age difference in mastery time becomes trivial. In rapidly changing occupations that require frequent training in new work methods, older workers may be more costly to the employer and less productive than younger workers (*see* Learning).

Laboratory samples showed consistently larger age differences in training performance than field samples. There are two methodological issues that may exaggerate the actual age differences in training. First, designs typically employed in age training research are extreme group designs. The performance of a younger group of employees (i.e., 23 years old) is compared with a significantly older group (i.e., 55 or 60 years old). Although designs of this kind may accurately assess the difference between the groups, it may exaggerate the degree of the relationship between age (as a continuous variable) and training performance. Second, there may be a bias in the selection of tasks in the lab so as to maximize the possibility of finding large age differences. In the field with real-world tasks, there is more variation in tasks as well as the possibility that practice and experience can counter age-related decrements.

Age and Work Attitudes

An extensive review of the work attitude literature indicates that consistent age-related differences exist in a number of attitudes. Overall job satisfaction has consistently been shown to be positively (but weakly) related to age. This relationship may be moderated by occupation. Human services and white-collar jobs had the strongest relationships between age and job satisfaction, whereas in factory, clerical, and teaching jobs, there appears to be no relationship between age and job satisfaction. In addition, other research suggests that tenure (which is typically strongly associated with age) is a more consistent predictor of job satisfaction than age. Research on facet satisfaction shows that there is, in general, a positive relationship between age and satisfaction with the work itself, whereas studies of satisfaction with pay have produced mixed results. Furthermore, satisfaction with promotion, the supervisor, and co-workers appears to be unrelated to age. This pattern of relationships is consistent with research suggesting that job characteristics may explain the age–job satisfaction relationship in that older employees appear to obtain more intrinsic rewards (but not necessarily extrinsic rewards) out of work than younger employees.

Studies of work values suggest that there may be a positive relationship with age. Although age typically is positively related to job involvement, a number of studies suggest that age may be less important than job and organizational characteristics, as well as

individual differences in determining level of job involvement. A recent meta-analysis showed moderately positive relationships between age and both Protestant work ethic and prestige (the effect a job has on a person's social standing). However, age was not found to be related to Maslow's concept of growth need strength or autonomy.

A number of theoretical models have included age as an antecedent of organizational commitment. Two forms of commitment have been extensively investigated in the literature, including affective commitment and continuance commitment. For affective commitment, it is assumed that as employees age, they become increasingly attached to the organization and their identification with the employer increases. In contrast, for continuance commitment, age is viewed as a factor that constrains future employment options due to non-portable investments in the organization. This makes leaving more costly, leading to higher levels of continuance commitment. A recent meta-analysis suggested that age is more strongly associated with affective commitment than with continuance commitment, but that age is not strongly related to either form of commitment.

In conclusion, although age does appear to be fairly consistently associated with overall job satisfaction and some types of work values, there is less evidence to support links between age and other attitudinal variables. In addition, there is fairly compelling evidence that even when age is associated with work attitudes, other variables, such as job and work conditions, may in fact account for these associations.

Age and Alternative Work Options and Schedules

Both older employees and management can mutually benefit from work arrangements other than the standard 40-hour schedule. Six different job arrangements have been identified in industrial gerontology that can be used effectively to accommodate the work needs of older workers and their employers. These work arrangements can be categorized into two groups: part-time work schedules and job modifications. Increasingly, organizations are experimenting with various forms of part-time employment for older personnel, including job sharing and phased retirement programs. Part-time reemployment of retirees is also an option. Job sharing usually involves two part-time employees sharing one full-time position. In this arrangement, work time is reduced, yet an older individual's expertise and experience, as well as the opportunity to mentor, continue to be available to the organization.

Phased retirement is an option for full-time employees who are 2–3 years away from retirement. In this option, employees are allowed to reduce their weekly work hours from 40 to 30 and then later to 20 hours until retirement. An individual can literally phase into retirement. This slow reduction of hours allows the organization the time to train and replace workers. Reemployment of retired workers on a part-time basis, in which the retiree is retained as a consultant or is rehired on a temporary basis, has become common in fast food industries, banks, and insurance companies. In a random sample of more than 400 organizations, approximately 25% had job sharing programs and another 25% had phased retirement programs. Nearly 50% were reemploying their retirees. These part-time work options appear to be reasonably popular methods for utilizing older personnel.

In contrast, a smaller number of organizations, for example, those within the manufacturing industry, make changes in the actual work performed by older workers. Three kinds of modifications are typically used with older employees: job design, job transfer, and job retraining. Job redesign involves either restructuring the work to be performed or reshaping the physical environment of the worker, for example, special chairs, magnifying glasses, and so forth. A number of these accommodations may fall under the 1991 American with Disabilities Act. Job transfer involves moving an older employee to a less physically or mentally demanding job. Finally, job retraining involves updating the skills of older experienced workers to keep pace with changing technology in their field. This occurs often in engineering-related fields.

Promotions, Challenging Assignments, and Career Plateauing

Most career theories include stages in which before retirement, individuals become 'obsolete' or 'deadwood' in preparation for leaving their employer. This commonly accepted view is inconsistent with the evidence that adults make many career transitions throughout their life span. Furthermore, many individuals in their 60s, 70s, and 80s continue to work and seek ways to expand their careers. Nonetheless, many organizations have strongly held belief systems about the age-related nature of careers, so that promotion and development systems are often designed for younger workers.

One factor that may contribute to lack of career development opportunities for older workers is the negative ways in which these individuals are often viewed. These negative features, however, are often viewed as essential to good performance, and organizations are likely to seek leaders with these types of attributes. Older workers are rated high in attendance,

solid performance record, and punctuality. These attributes are likely to be associated with reliable and dependable employees but also with those who may be viewed as unlikely to advance. These studies also suggest that younger workers may be seen as more appropriate for the types of challenging jobs that many employees are currently faced with in times of downsizing, mergers, and acquisitions. Longitudinal research further indicates that challenging assignments early in one's career are highly predictive of upward career mobility.

Age stereotypes may contribute to less development of older workers than younger workers. Older workers are viewed as resistant to change and are given less feedback and fewer opportunities to improve their performance. Furthermore, research suggests that the age composition of the work group may affect the degree to which older workers receive developmental opportunities. Older workers who work with other older employees are least likely to receive career counseling. In contrast, older workers are most likely to receive on-the-job training when they work with younger people. Nonetheless, older workers are much less likely than either younger or middle-aged workers to receive career counseling and on-the-job training. This shows that although age context affects the degree to which older workers receive developmental opportunities, older workers are still the least likely to receive those opportunities.

Again, age stereotypes may underlie differential performance attributions made about younger and older workers, limiting the upward mobility of older employees. Poor performance by older workers is attributed to more stable factors, such as ability, than similar performance by younger workers. In addition, job simplification is viewed as more appropriate and training (for more demanding tasks) as less appropriate for poorly performing older workers. Older employees are also viewed as causing their own career problems due to loss of motivation or complacency. Thus, differential performance attributions may also explain why older workers receive fewer developmental opportunities than younger workers.

Research on promotability suggests that age context plays an important role. Although middle-aged and older workers are viewed as most promotable when they work with people who are younger than they are, younger workers are seen as most promotable when they work with people who are older than they are. Similar findings have been shown in the performance appraisal area. Managers who are younger than most other managers at their organizational level receive higher performance ratings than those who are older than most others at their organizational level. Because performance ratings are often used in making promotion decisions, this suggests that being younger than the norm may have some distinct career advantages in terms of promotion opportunities.

The pattern of results for studies of developmental opportunities, promotability, and performance suggests that age stereotypes may adversely limit older workers' career opportunities. Age stereotypes regarding older workers' capabilities, willingness to change, and technical obsolescence surely lead to career plateauing and stagnation. Promotion denials for older employees may be more common than outright dismissals and are a frequently cited basis for lawsuits under the ADEA. However, denial of promotion based on age is more difficult to prove than an illegal dismissal. Future research is needed that addresses methods for overcoming stereotypes that limit opportunities for older workers.

Age Discrimination

Although many charges are dropped by the Equal Employment Opportunity Commission (EEOC) due to lack of evidence, some cases do make it to court. The overwhelming percentage of plaintiffs in age discrimination suits are men, especially senior white male professionals and managers. The greatest number of cases concern wrongful termination. Employees tended to lose their cases in court, possibly because in strong cases (for the plaintiff), organizations settled out of court, and employers carried through only on cases they felt sure of winning. Women were more likely than men to win their cases (64 vs. 29%), although these comparisons should be made cautiously due to the small number of women filing age discrimination claims. Regardless, there are some organizational practices that may be indicative of age discrimination, including older workers being passed over in favor of younger workers with similar credentials, being told that no openings exist when they do, being discouraged from jobs by using 'too much experience' as a proxy for age, being replaced by younger workers with the same or fewer skills, being denied opportunities to participate in training programs, being considered not promotable, being laid off before younger workers, being paid less for the same work, being demoted without just cause, and having challenging assignments transferred to other younger workers.

Exiting the Organization

Economics of Age

Many employers seem to believe that older workers are more costly (relative to their productive value)

than younger workers. There is evidence that there are age-specific costs for benefit pension plans and health insurance for active workers. Retiree health insurance plans provide a strong disincentive to hiring older workers not yet eligible for Medicare. Health costs and other compensation costs are greater for older workers despite the finding that most older workers are healthy enough to keep working longer than they do. Wages and salaries tend to increase up until age 50 or so and then level off (e.g., older workers typically earn more than younger workers). During layoffs, downsizing, and mergers, the financial savings realized by reducing the number of more highly paid older workers may be attractive for organizations in the short run. Using salary as a basis for layoff decisions has been ruled acceptable by some US courts even though it disparately impacts older workers.

Proponents of reducing the number of older workers may overlook costs associated with recruiting and training new employees. Further costs are incurred in relocating new workers, assisting spouses in finding work, and the learning curve associated with new workers adjusting to the new work environment.

Age and Turnover

Several reviews suggest that age is negatively related to turnover. However, a recent meta-analysis showed that age provides little useful information about whether an employee will voluntarily leave an organization. However, given the measurement problems associated with turnover (i.e., the wide variety of measures used), the relationship between age and turnover may be underestimated. Intentions to quit and propensity to leave have been found to be the best predictors of voluntary turnover. Older workers consistently show lower turnover intentions. Since older workers tend to have lower voluntary turnover rates than younger workers, this may actually counterbalance the greater costs of benefits. That is, greater stability of an older workforce may offset disadvantages associated with high fringe benefit costs.

Age, Job Terminations, and Retirement

Downsizing is an increasingly popular organizational strategy for reducing costs. Downsizing methods include voluntary severance programs, voluntary early retirement programs, attrition, relocation, pay and hiring freezes, and outright firing. Information is not available on the extent to which older workers are affected by downsizing relative to other age groups. However, voluntary early retirement programs, which have been a very popular downsizing method, are clearly targeted toward older groups. Many of those who take early retirement do so voluntarily, partially due to dissatisfaction with the job, supervisor, and company. Some also recognize the lack of promotion opportunities available to them and thus opt for retirement. However, others are forced to take early retirement or face the prospect of termination. Of particular concern are organizations that change performance appraisal systems or ratings to justify the desire to rid themselves of older workers. Abrupt changes in the performance appraisal system are likely to create mistrust, not only among those who are retiring, but also possibly for those who remain with the organization.

A great deal of research has focused on factors that predict retirement. These factors can be divided into three major categories: personal variables, work-related factors, and environmental factors. In terms of personal factors, the date people choose to retire is influenced by eligibility for a pension plan and their anticipated financial situation at retirement. Health is another personal variable that is related to when people retire. It has also been found that people who anticipate adjusting well to retirement are more likely to plan an early retirement. For work-related factors, a number of studies suggest that work satisfaction may influence when people retire. Unlike for younger workers, organizational commitment is not a good predictor of turnover for older workers. Overall, the evidence for work attitudes as predictors of retirement is not overly compelling. Environmental factors can include family and marital situations (being widowed or still have children in college), as well as leisure activities. Individuals with strong interests outside of work may opt to retire early in order to pursue those interests.

It is not entirely clear what the impact of retirement is on employers. Large numbers of retirements may provide more career opportunities for young people and allow organizations to hire people with up-to-date skills. On the other hand, organizations may lose critical knowledge or skill areas that older, more tenured workers provide. One study found that an early retirement program did not have a substantial effect on the firm's management talent, nor was there any indication that the most capable managers were the most likely to retire early. Moreover, it appeared that the more highly motivated managers with more positive attitudes toward their work and toward the company were less likely to retire. However, additional research is clearly needed in this area to determine whether these results generalize to other organizations (*see* Retirement).

Approaches to Understanding Age at Work

Stereotypes of Older Workers

The negative stereotypes of older workers have been documented in the industrial gerontology and industrial and organizational psychology literatures. Older workers are perceived as less efficient, less creative, less promotable, more resistant to change, slower, disinterested in training or retraining, incapable of adapting to change, undependable, costly, unable to meet the physical and mental demands of work, more rigid, and prone to illnesses and accidents. Furthermore, older workers are viewed as more passive, reserved, obsolete, and inflexible than younger workers. Some human resource managers believe that older workers have different work styles, which clash with the work style of younger workers. However, as people age, some positive characteristics are ascribed to them. For example, older people have also been described as more reliable, loyal, careful, and conscientious than their younger counterparts. Older workers are perceived to take longer and take fewer risks in decision making than younger managers. However, when risks must be taken and decisions made quickly to avoid missing an opportunity, these characteristics may be viewed as a potential negative. Although attitudes toward older workers are generally more negative than attitudes toward younger workers, the magnitude of the difference decreases as the age of the perceiver (the rater) increases. Furthermore, negative perceptions of older workers may play a greater role in some occupations than in others. Older employees in jobs typically occupied by younger persons or requiring skills associated with younger incumbents may be perceived most negatively, whereas older employees in positions occupied by or associated with older individuals may be perceived positively and in nonstereotypic terms (*see* Ageism and Discrimination).

Relational Demography Using relational demography, older workers in older workgroups and younger workers in younger workgroups should experience more positive work outcomes than individuals in workgroups that are dissimilar in age to the target employee. Relational demography draws from both the similarity-attraction paradigm and social identity theory and suggests that similarity to referent others results in favorable outcomes while dissimilarity results in unfavorable outcomes. Further, individuals categorize themselves into meaningful social categories to allow them to maintain positive self-identities. Research has shown support for relational demography when employee age relative to the workgroup has been examined.

Career Timetables The notion of career timetables suggests that age differences may have either positive or negative effects depending upon clear norms regarding where one should be on the organizational chart at a given age. For example, employees who are promoted at a rate similar to their peer group are viewed as 'on schedule' while those who are promoted more quickly are considered 'ahead of schedule' and those who are promoted less often than their peer group are considered 'behind schedule.' The latter two groups both reflect target mismatches, yet the career timetable makes very different predictions about these two groups. Managers who viewed themselves as behind schedule reported lower work satisfaction and work orientation. On the other hand, managers who were ahead of schedule received the highest performance ratings, while behind schedule managers received the lowest performance ratings.

Although the career timetable approach focused on the work group as the referent, other research supports this approach using the manager or the supervisor as the referent. That is, when employees are older than their managers, older workers received the fewest development opportunities and the lowest potential and promotability ratings.

Prototype Matching In the prototype matching approach, the individual's age is compared to the age of the typical incumbent for a given job. A number of studies support the existence of both job and occupational prototypes. This approach suggests that through a cognitive matching process, greater matches between target age and job age prototype result in more favorable selection outcomes and greater mismatches produce less favorable outcomes. Much of the empirical research on prototype matching has studied its impact on selection. More recently, research shows partial support for prototype matching for other decisions, including promotions. In general, research shows mixed support, suggesting that other contextual variables may influence the matching process.

Future Research Issues Concerning Older Workers

The aging of the population in the United States and other industrialized countries needs to be considered in future research and public policy initiatives. This trend reflects both a decline in fertility rates as well as an increased life expectancy. The large baby boom generation moves into normal retirement age between 2011 and 2030. The US Census Bureau predicts that

the present percentage of the population over 65 will rise from the current 13% to 20% in 2050 and 23% by 2100. Furthermore, recent research shows that the employment rate of 55- to 64-year-olds in many industrialized countries is somewhat low, for example, 29.9% in Italy, 38.8% in Germany, 57.7% in the United States, and 63.8% in Japan. Most initiatives to date that encourage older employee participation in the workforce appear largely motivated by economic concerns. Such initiatives are too narrow in focus, and do not consider the key stakeholders that would encourage such continued participation, including governments, employers, professional organizations, and the older workers themselves. This suggests the importance of research on age diversity in work settings, in particular, research examining predictors of age discrimination as well as the potential underutilization of older workers' skill and knowledge due to stereotypes and traditional assumptions about career progression. Furthermore, research examining retirement decision making, with particular emphasis on organizational factors that encourage or discourage retention of older workers, is needed. It is important that such research occur in the near future prior to a potentially large exodus of workers, as the research suggests little proactive efforts to date that address the retention and maximization of the productivity of older populations of employees.

Older Women

Workforce participation rates for women have increased dramatically during the last four decades. For women from 55 to 64 years, participation rates rose from the early 1940s and peaked during the late 1960s. Since the 1980s participation rates have leveled off at approximately 41.7 women in the labor force for every 100 men. In 1987, 56% of women were working, and on average, the woman was married, a mother, and had a high school education. Participation rates of women aged 65 and over reached their record highs between the mid-1950s and 1960s when they ranged from 10.2 to 10.9 for every 100 women in the population. By the mid-1980s, the participation rates drifted downward to 7.5. Furthermore, the proportion of older women who work continues to be substantially lower than the proportion of older men; the proportion who retire early is somewhat higher than for men. Thus, the typical female employee does not resemble the typical male employee. Furthermore, middle-aged and older women are a heterogeneous group in terms of skills, work life expectations, centrality and necessity of work, child-care responsibilities, and elder-care responsibilities. Some researchers have speculated that different standards of aging exist for men and women. Because women are more likely to be judged on their physical appearance than men, women are viewed more negatively as they age. In contrast, as men age, their prestige may be enhanced by increased money and power, and they are judged less on their physical appearance. Some authors have argued that these different standards for judging men and women affect women in the workplace, such that women may be devalued at work at an earlier age than men. Perhaps some of the 'glass ceiling' effects that women experience are partially due to the devaluation of women that occurs as they age. Women may have fewer career opportunities not just because of their lower status in the workplace, but also because of the way in which society views older women. Clearly, future research needs to examine the interactive effects of age and gender to determine whether men and women are treated differently as they age.

Age and Minority Status

In 1980, about 17% of ethnic minorities in the United States were over 65 years. This proportion of the population is growing more rapidly than the White population. Very little research to date has been conducted in this area. Generally, however, older minority males and females tend to be worse off economically and in terms of employment than their non-minority counterparts. With significantly increasing diversity, there is a great need for the existing and future research in this area to be highlighted and mainstreamed in major gerontological and work employment research and practitioner journals. If minorities are concentrated in occupations that require physical labor, speed, and routinization of tasks, minority employees may be at greater risk for potential negative experiences resulting from age bias. Furthermore, because lower-level employees are in the most financial need of work, once retired they are often forced (due to their age) to accept lower-paying jobs if they can find them. Women, Blacks, and Hispanics experience severe hardships because they often lack financial reserves and pension plans and find it harder to gain reemployment at an adequate wage.

Current Organizational Issues

Working in Teams In some types of work groups, there may be a generational problem for older workers. Younger groups may be better able to draw on the performance of the best individuals (e.g., the most knowledgeable) and to identify and use their members' resources. In older groups, members may be more concerned with establishing and preserving

status and leadership and avoiding looking bad to peers. Research suggests that younger people, as compared to older workers, may have more experience in group-process work and group decision making, have less concern with status and control, have less competition in a group, and are more focused on securing optimal results on the task. Furthermore, studies of older managers suggested that they were less often in teams (except in competitive situations), believed informal teams were viewed as cliques and were to be avoided, did not know much about working cooperatively, had been raised in autocratic modes of management and saw asking for or accepting help as a sign of weakness, relied on 'experts', and even when committed to teamwork, lacked the skills needed to make it work. Given the trends toward approaching work using teams of people, this research suggests that older workers who are expected to operate in and contribute to group activities may need to be trained or counseled in how to be effective group members.

Unfortunately, research on the role of mixed age groups on team work is quite limited. However, it could be argued that the knowledge and experience of older workers, along with the team orientation of younger workers, if effectively managed through various organizational interventions (e.g., training and coaching), along with team-based compensation, could yield very effective team processes. Future research is needed that examines factors that encourage effective team function in diverse (mixed age) teams.

Older Workers and Technology High technology, including computer-integrated manufacturing and robotics, frees many workers from hard physical labor and increases the need for workers with a wide range of technical and problem-solving approaches. Jobs created by robotic technology often require at least 2 years of college education as well as additional training and retraining. Technology has influenced work site location. Certain regions of the country have attracted a significant proportion of information-processing and smaller high-tech companies. The computer has played a large role in the development of telework and telecommuting, specifically working from one's home or neighborhood satellite offices. These and other technological changes will affect the increasingly diverse workforce. Older workers will not fare well if speed is a necessary characteristic of working with technology. On the other hand, work that is not contingent on physical labor and that requires alternative methods of problem solving may be a positive source of employment for the older employee. More research is needed to determine how people's perceptions of older workers influence their judgments about their employability in such occupations.

Older Workers and Customer Service Orientation Most of the new job opportunities since 2000 have been in the service sector. Older workers may be appropriate for these jobs, which are assumed not to be physically demanding. However, thorough job analyses of these jobs is necessary because many service positions are stressful and demanding (e.g., nursing, food counter work). For some service positions, task-related experience may be an important requirement. The majority of the occupations with the largest projected job growth are female dominated, including retail sales positions, nurses, secretaries, receptionists, food preparation positions, and teachers (secondary school and kindergarten). Hopefully, a proportionate number of these jobs will go to older women, especially because this is a rapidly expanding group in the workforce.

Generation Issues Research has shown that people of all ages hold stereotypes of other age groups, attributing various physical, intellectual, social, and psychological characteristics based on age. For example, baby boomers (born between 1943 and 1960) view generation Xers (those born between 1961 and 1981) as bleak. Generation Xers were much more likely than baby boomers to be latchkey kids, learning to take care of themselves at an early age. They are more likely than prior generations to change jobs frequently, perhaps in reaction to the treatment their parents received of being rewarded for loyalty and long work hours with layoffs and loss of pensions. Generation Xers put an emphasis on skill variety to enhance marketability, flexibility in work hours, performance-related feedback, and short-term rewards. In contrast, fewer managerial positions means fewer upward movement opportunities, and those available are often held by baby boomers.

Generation Xers are interested in leisure activities and do not want to devote themselves entirely to the welfare of the company. Thus, research shows that baby boomers view generation Xers as disrespectful of authority, low in loyalty, and unwilling to pay their dues. Such generational stereotyping and differences in work and lifestyle preferences are likely to affect relations at work. Research is clearly needed to examine generational as well as age effects and to determine the separate impact of each on a variety of organizational processes and outcomes.

Conclusions

Research on age and employment shows that age affects many work processes. Yet many studies of the

same work process (e.g., hiring, performance evaluation) show inconsistent results. This may be largely due to the influence of the work context and age stereotypes. Contextual variables such as age composition of departments or applicant pools, occupations, and jobs all appear to influence decisions about older workers. Furthermore, age stereotypes of workers and of tasks may serve to limit older workers' career opportunities and may encourage early retirement programs and other forms of downsizing that can adversely affect older workers. More systematic research is needed to better understand how the work context and age stereotypes affect older workers. More theory development pertaining to older working adults is needed. Given the aging of the workforce, research and theory focused on the role of aging at work is particularly timely.

See also: Ageism and Discrimination; Attention; Learning; Memory; Motor Control; Perception; Retirement.

Further Reading

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Work and Employment: Society

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Glossary

European Equal Treatment Directive – A year 2000 directive requiring all 15 EU- as of 2004, all 25 countries- to introduce legislation proscribing discrimination in terms of labor, market activities and training on the grounds of age.

Background

This article considers the issues of extending working lives and promoting age equality, with a particular focus on recent policy developments among European Member States. This is justified on the grounds that while all developed nations experienced a trend toward early retirement in the second half of the twentieth century, it was parts of Europe where this was most pronounced as policy makers sought to manage youth unemployment and industrial restructuring in the 1980s and 1990s, and it is in the area of prolonging working lives that European policy makers have taken particular interest in recent years. By contrast, early retirement on this scale never existed in Japan or the United States. However, in both Japan and much of Europe, declining fertility levels are predicted to have a profound effect on labor supply and consequently, economies. By 2030 the European Union (EU) can expect 14% fewer workers and 7% fewer consumers than there are today, while Japan, over the same period, will experience declines of 18% and 8%, respectively.

However, Europe alone is also dealing with the legacy of early retirement. An Organisation for Economic Co-operation and Development (OECD) study found that, among nine European Union countries, the share of older workers among recent job hires was almost 13 percentage points lower than so-called prime-age workers. Age-related labor market barriers are the result of the complex interplay of a number of factors, including stereotypes concerning the capabilities and motivations of older workers and the existence of early retirement pathways. One view is that companies' policies are indirectly determined by community norms, representations, and stereotypes of younger and older workers. However, others

argue that age is rarely explicitly considered by management or unions and that corporate policies and programs have differential effects on older and younger workers, but these are mostly unintended. Instead, early exit is primarily the result of staffing calculation methods, a desire to maintain harmonious industrial relations, the opportunity to use early retirement mechanisms, and the age structure of workforces.

European policy makers are beginning to turn their backs on early retirement. Instead, the new mantra is one of prolonging working lives as population aging exerts pressure on social welfare systems. This article speculates on the implications for older workers. It begins with a brief overview of the situation of older people in the European labor market, before moving on to discuss European-level actions that are expected to influence public policy at the national level. Next, actions on the part of selected countries are discussed, before conclusions are drawn concerning the prospects for older workers and the state of knowledge.

Statistical Overview: The Aging Labor Force and Trends in the Participation of Older Workers

This section covers trends in economic activity, unemployment, and employment rates, and the average age of retirement from employment. **Table 1** demonstrates the low levels of employment of older workers in EU countries against the OECD average, while **Table 2** also demonstrates variation among European member states. Overall, the most recent members of the EU have had average activity rates some 10 percentage points lower than the previous EU-15. While useful, it should be acknowledged that such comparisons need to be interpreted with caution. For instance, the apparent advantage in terms of employment rates among older workers in the UK compared to Germany is reduced when part-time employment is considered.

Table 1 Employment rates among workers aged 55–64

		Employment rate (%)				
		1990	*2000*	*2001*	*2002*	*2003*
EU 15						
	All	38.5	38.3	39.3	40.6	42.3
	Men	53.2	48.5	49.4	50.6	53.2
	Women	24.9	28.5	29.6	31.0	31.8
OECD						
	All	48.4	47.9	48.5	49.4	50.8
	Men	63.7	59.5	59.8	60.5	62.0
	Women	34.3	37.1	37.7	38.9	40.3

Source: OECD Employment Outlook 2004.

Employment population ratios for men and even more for women decline significantly in the UK when adjusted for part-time employment, whereas in Germany they increase for men and decrease less for women than in the UK. In consequence, the difference in employment rates for older workers, while still in evidence, is less pronounced.

Table 3 compares average life expectancy at 60 with the overall average age of exit from the labor force for the EU. **Table 4** adds to this by providing an additional gender breakdown. These tables are indicative of different pressures facing member states due to demographic aging. For example, in the year 2000, French men could expect to live for over 20 years on average at age 60, while women could expect to live for over 25 years. This compares with an average age of exit from the labor force of just over 58 in 2001. Compare this with the United Kingdom, where in 2000 men could expect to live over 19 years at age 60, and women 23 years. However, the average age of retirement was 62 in 2001.

Table 5 takes a wider perspective still, comparing Europe with Japan and the United States in terms of employment rates over time. This shows a huge gap between Europe and these countries, with employment rates among older workers some 20% higher in Japan and the United States than the EU-15, and even more so when compared to the EU-25, though between 1997 and 2002 the EU closed the gap slightly with the United States, while employment among older workers in Japan fell.

European Public Policy on Age and Employment

The employment of older workers has only recently become an issue for European policy makers. Three agreements should be influencing public policy at national levels. These are the European Equal Treatment Directive, and the Barcelona and Stockholm targets. In the year 2000 EU Council Directive 2000/78/EC established a framework for equal treatment in employment and occupation. The Directive requires all 15 EU – as of 2004, all 25 – countries to introduce legislation proscribing discrimination in terms of labor market activities and training on grounds of age. The directive allows member states until the end of 2006 to implement the provisions on age. A recent review concluded that transposition of the directive has been uneven, with little progress being made in Germany, while France and Italy have complied technically, though more could be done.

The European Council of Stockholm in 2001 agreed on an ambitious target for the employment

Table 2 Employment and economic activity rates of older workers in 2002 (preliminary results)

	Employment rates (% population aged 55–64)			*Activity rates (% population aged 55–64)*		
	Total	*Male*	*Female*	*Total*	*Male*	*Female*
EU15	40.1	50.1	30.5	42.8	53.4	32.5
Belgium	26.7	36.1	17.6	27.8	37.6	18.4
Denmark	57.8	64.5	50.4	60.4	67.0	52.9
Germany	38.4	47.1	29.9	43.0	52.3	33.9
Greece	39.7	56.0	24.4	41.4	58.1	25.5
Spain	39.7	58.6	22.0	42.7	62.2	24.4
France	34.8	39.3	30.6	36.7	41.8	31.9
Ireland	48.1	65.1	30.8	49.3	66.7	31.6
Italy	28.9	41.3	17.3	30.2	43.0	18.1
Luxembourg	28.3	37.9	18.6	28.3	37.9	18.6
Netherlands	42.3	54.6	29.9	43.3	55.8	30.6
Austria	30.0	39.8	20.9	31.8	42.9	21.5
Portugal	50.9	61.2	41.9	52.9	63.5	43.5
Finland	47.8	48.5	47.2	52.1	53.0	51.2
Sweden	68.0	70.4	65.6	71.2	74.3	68.2
United Kingdom	53.5	62.6	44.7	55.4	65.4	45.7
AC10	30.5	41.2	21.4	33.1	45.0	23.0
AC12	31.6	41.1	23.5	34.0	44.6	25.0
EU25	38.7	48.9	29.1	41.4	52.3	31.1
EU27	38.5	48.5	29.0	41.1	51.8	31.0
Cyprus	49.2	67.0	32.1	50.8	68.8	33.7
Czech Republic	40.8	57.3	26.0	42.5	59.4	27.3
Estonia	51.6	58.4	46.5	55.7	63.7	49.8
Hungary	26.6	36.7	18.5	27.5	38.2	18.9
Lithuania	41.6	51.5	34.1	46.9	59.8	37.2
Latvia	41.7	50.5	35.2	46.3	57.1	38.2
Poland	26.1	34.5	18.9	29.1	38.7	20.9
Slovenia	24.5	35.4	14.2	25.2	36.7	14.5
Slovak Republic	22.8	39.1	9.5	26.9	46.3	11.1
Bulgaria	27.0	37.0	18.2	31.8	43.7	21.5
Romania	37.3	42.7	32.6	37.9	43.9	32.8

Source: Annual averages based on LFS, Eurostat. Cited in *Employment in Europe: Trends and Prospects*, EURES, 2003.

rate of older workers of 50% by the year 2010 (from 38.8% in 2001). **Table 6** shows that only a handful of countries have achieved this target so far.

The Barcelona European Council agreed on an increase of 5 years in the average age at which people stop working in the EU by 2010. The average exit age in the EU was 59.9 years in 2001. As **Table 4** shows, progress so far has been modest.

In considering progress toward achieving these European objectives, it is worth reflecting on the legacy of early retirement and the way it has been used as a tool for reducing labor supply in order to open up job opportunities for younger people. As **Table 7** shows, among European countries, youth unemployment is a persistent problem, and this may be undermining efforts to promote the employment of older workers.

Thus, European member states face immense challenges in the coming decades in tackling the issues associated with the aging of their labor forces. The following sections focus on national actions, with those of certain member states provided as exemplars.

Strategic Approaches

European institutions, the OECD, and most independent observers would argue for a comprehensive and integrated approach to tackling age barriers in the labor market. However, policy making at the national level in Europe, with one or two exceptions, could be characterized as largely ad hoc and piecemeal. The best known example of a comprehensive approach is the Finnish Program on Ageing Workers (1998–2002). The UK has also sought to coordinate activities across government departments, with some success.

Elsewhere, the Czech Republic has responded to the aging of its population by devising the National Program of Preparation for Ageing (2003–07). Areas for action include the following:

- Equal rights and opportunities
- Lifelong learning and special training measures for older workers
- Attitudes to aging and older persons

Table 3 Life expectancy at the age of 60 and average exit age from the labor force in the EU and acceding countries (AC10)

	Life expectancy at 60 in 2000		*Average exit age from the labor force in 2001 (men and women)*
	Men	*Women*	
Belgium	19.3	23.8	57.0
Denmark	18.9	22.3	61.8
Germany	19.2	23.4	60.7
Greece	20.1	23.1	59.6
Spain	19.8	24.5	60.6
France	20.2	25.3	58.1
Ireland	18.3	21.9	62.9
Italy	19.7	24.1	59.4
Luxembourg	19.3	24.1	56.8
Netherlands	19.1	23.4	61.0
Austria	20.0	23.9	59.5
Portugal	18.5	22.6	62.1
Finland	19.2	23.6	61.5
Sweden	20.7	24.3	62.1
United Kingdom	19.4	23.0	62.0
Cyprus	19.5	22.7	62.3
Czech Republic	17.0	21.2	59.2
Estonia	15.4	20.9	61.1
Hungary	15.3	20.2	57.9
Lithuania	16.8	21.9	57.8
Latvia	15.3	20.8	62.2
Poland	16.7	21.4	56.6
Slovenia	17.6	22.7	61.5
Slovak Republic	15.9	20.6	57.9
EU15	19.3	23.7	59.9

Source: Life expectancy, demographic statistics, Eurostat. I, 1996; EU, CY, 1997; D, E, EL, F, 1999; remaining countries, 2000. Average exit age from the labor force, methodology, DG Employment and Eurostat. Cited in *Employment in Europe: Trends and Prospects*, EURES, 2003.

- Social and economic integration of older persons
- Making better use of the capabilities of older workers, e.g. in mentoring roles
- Labor mobility and flexible employment opportunities
- Individual preparation for aging and old age.

The Czech Action Plan for Employment of 2002 proposes an increase in the participation of older unemployed persons in active labor market measures. Interestingly, in the Czech Republic two pilot initiatives offered on a voluntary basis that helped individuals aged under and over 25 to develop individual employment action plans appear to have reduced the likelihood of long-term unemployment. However, new proposals oblige official labor offices to now offer these to the former, while there appears to be greater flexibility regarding the latter.

In 2001 in the Czech Republic, a new regulation was passed that made early retirement more disadvantageous and employment after retirement age more advantageous. If a non-working person takes a job they may no longer lose full benefits. There was a marked decrease in the share of early retirement pensions as a proportion of newly awarded pensions in 2002. However, schemes that encourage early retirement still exist in industries such as steel, mining, and railways.

Reform of Retirement Income Systems

It is in the area of retirement income systems that most recent reforms have taken place in the EU. Yet early exit remains both popular and possible. For instance, despite recent reforms ostensibly aimed at maintaining older workers in employment, a deep early exit culture exists in France, and against this backdrop, few firms, it seems, have developed policies around the employment of older workers and there is not a widespread belief that population aging will necessitate such a reorientation. Moreover, policy making is deeply contradictory, with efforts to extend working life undermined by pressure to tackle unemployment, often at the expense of older workers. Employers, unions, and workers have colluded in the perpetuation of a system in which 55 has become the normal age of retirement, while those in their 40s are now viewed as 'nearly old' and face reduced employment prospects.

In its pension reforms the French government is trying to reduce numbers of those opting for early retirement. The contribution period before an individual is eligible for full pension benefits has been increased, while the age at which a person automatically retires has been increased from 60 to 65. The new pension system provides incentives for those who work beyond 60. Gradual retirement is also being extended. On the other hand, in 2003 a redundant worker aged 56 could receive unemployment insurance benefits worth up to 75% of his or her previous salary for up to 3.5 years, with no job search requirement. Added to this, this period could be counted in the calculation of a pension. Moreover, early pensions are still popular, for example, in the motor industry, while there has been considerable public resistance to pension reform.

Similarly, in Hungary pension reform has taken center stage, alongside a major overhaul of the welfare state more generally. The retirement age increased for men from 60 to 62 in 2002 and will increase for women from 55 to 62 by 2009. An increase of the legal retirement age to 65 years for both sexes is expected between 2015 and 2020. In addition, the minimum contribution period is increasing gradually and will be 20 years by 2009.

Table 4 Average exit age from the labor force

	2001			*2002*			*Change 2002–2001*		
	Total	*Men*	*Women*	*Total*	*Men*	*Women*	*Total*	*Men*	*Women*
Belgium	56.8	57.8	55.9	58.5	58.6	58.4	1.7	0.8	2.5
Denmark	61.6	62.1	61.0	60.9	61.9	59.8	−0.7	−0.2	−1.2
Germany	60.6	60.9	60.4	60.7	61.1	60.3	0.0	0.2	−0.1
Greece	59.4	61.2	57.7	.	.	.	.	.	.
Spain	60.4	60.7	60.2	61.5	61.5	61.5	1.1	0.8	1.3
France	58.1	58.2	58.0	58.8	58.9	58.7	0.7	0.7	0.7
Ireland	62.8	63.2	62.5	62.4	62.0	62.8	−0.4	−1.2	0.3
Italy	59.8	59.9	59.8	59.9	60.2	59.7	0.1	0.3	−0.1
Luxembourg	56.8	.	.	59.3	.	.	2.5	.	.
Netherlands	60.9	61.1	60.8	62.2	62.9	61.6	1.3	1.8	0.8
Austria	59.2	59.9	58.5	59.3	59.4	59.3	0.2	−0.5	0.8
Portugal	61.8	62.1	61.6	62.9	62.8	63.0	1.1	0.7	1.4
Finland	61.4	61.5	61.3	60.5	60.6	60.4	−0.9	−0.9	−0.9
Sweden	61.7	61.9	61.6	63.2	63.4	63.1	1.5	1.5	1.5
UK	62.0	63.0	61.0	62.3	62.7	61.9	0.3	−0.3	0.9
EU15	**60.4**	**60.8**	**60.0**	**60.8**	**61.0**	**60.5**	**0.4**	**0.2**	**0.5**
EU25	**60.0**	**60.6**	**59.4**	**60.4**	**60.8**	**60.0**	**0.4**	**0.2**	**0.6**
Czech Republic	58.9	60.7	57.3	60.2	62.2	58.4	1.3	1.5	1.1
Estonia	61.1	.	.	61.6	.	.	0.5	.	.
Cyprus	62.3	.	.	61.4	.	.	−0.9	.	.
Latvia	62.4	.	.	.	.	.	.	.	.
Lithuania	58.9	.	.	.	.	.	.	.	.
Hungary	57.8	58.5	57.3	59.2	59.6	58.8	1.3	1.1	1.5
Malta	.	.	.	.	.	.	.	.	.
Poland	56.6	57.8	55.5	56.9	58.1	55.8	0.3	0.3	0.3
Slovenia	61.5	.	.	.	.	.	.	.	.
Slovak Republic	57.5	59.3	56.0	57.5	59.6	55.7	0.0	0.3	−0.3

Source: Eurostat, Labor Force Survey, annual averages.
Notes: . = not available; provisional data for PL; spring data for D, F, L, and CY, average of quarter 2 and 4 LV and LT. Data based on overall activity rates (no adjustment by gender since data by sex lack reliability due to the low sample size) for L, EE, CY, LV, LT, and SI; estimation for 2002 for EU15 and EU25. Cited in Increasing the employment of older workers and delaying the exit from the labor market. Commission of the European Communities. Brussels 3.3.2004. COM (2004) 146 final.

Workers will also now receive an enhanced pension if they defer retirement. However, importantly, while pathways to early retirement have been partially closed, if individuals are willing to accept a financial penalty, they may retire at age 55 for women and 60 for men. Another feature of reforms has been the implementation of restrictions on access to disability benefits, with the addition of training programs in an effort to mobilize those with disabilities.

The primary focus of public debate in Italy has been pension reform, and attention has only recently begun to turn to the issue of re-activating older workers. Reforms include increasing the pension age to 65 for men and women, enhancements for pension deferral, increasing the minimum age for claiming a pension, part-time flexible retirement, and the opportunity to mix employment and pension income. A law of 2001 aimed to encourage the deferral of retirement by encouraging workers to move on to a temporary contract. However, take up has been low. Such reforms may be weakened by disinterest in part-time working. Nevertheless, the average age of retirement has risen since the mid-1990s, due in part to pension reforms. Though the increase to date has been modest (0.5 years for men and 3 years for women) it is predicted that new reforms will strengthen the trend.

In Poland pension reforms initiated in 1999 aimed to increase the average age of retirement. The Program of Limiting and Restructuring Social Security Expenditures of 2003 included proposals to equalize male and female retirement ages and to limit opportunities for early retirement. As part of pension reforms, those who have reached statutory pension age are allowed to work without limit. Few take this opportunity, though the numbers of those who do are increasing. Proposals include the possibility of partial retirement at age 62, though it is still possible to retire early without an obligation to seek work.

In Spain, new policies aim to reduce the incidence of early exit and prolong working life. For example, a measure to encourage long-term contracts among older workers has been implemented, though its effect has been slight. Additionally, to encourage older unemployed workers to re-enter the labor market, it

Table 5 Recent trends in employment rates among European Member States, Japan, and the United States

	1997		*2000*		*2001*		*2002*	
	15–64	*55–64*	*15–64*	*55–64*	*15–64*	*55–64*	*15–64*	*55–64*
EU15	60.7	36.4	63.4	37.8	64.1	38.8	64.3	40.1
EU25	60.6	35.7	62.4	36.6	62.8	37.5	62.9	38.7
ACC	60.1	31.6	57.4	29.6	56.6	29.7	55.9	30.5
USA[a]	73.5	57.2	74.1	57.8	73.1	58.6	71.9	59.5
Japan	70.0	64.2	68.9	62.8	68.8	62.0	68.2	61.6
Belgium	56.8	22.1	60.5	26.3	59.9	25.1	59.9	26.6
Denmark	74.9	51.7	73.3	55.7	76.2	58.0	75.9	57.9
Germany	63.7	38.1	65.6	37.6	65.8	37.9	65.3	38.6
Greece	55.1	41.0	55.7	38.6	55.4	38.0	56.7	39.7
Spain	49.4	34.1	56.2	37.0	57.7	39.2	58.4	39.7
France	59.6	29.0	62.1	29.9	62.8	31.9	63.0	34.8
Ireland	57.5	40.4	65.1	45.3	65.7	46.8	65.3	48.1
Italy	51.3	27.9	53.7	27.7	54.8	28.0	55.5	28.9
Luxembourg	59.9	23.9	62.7	26.7	63.1	25.6	63.7	28.3
Netherlands	68.5	32.0	72.9	38.2	74.1	39.6	74.4	42.3
Austria	67.8	28.3	68.5	28.8	68.7	28.9	69.3	30.0
Portugal	65.7	48.2	68.4	50.7	68.5	50.1	68.2	50.9
Finland	63.3	35.6	67.2	41.6	68.1	45.7	68.1	47.8
Sweden	69.5	62.6	73.0	64.9	74.0	66.7	73.6	68.0
United Kingdom	69.9	48.3	71.5	50.8	71.7	52.3	71.7	53.5
Czech Republic	.	.	65.0	36.3	65.0	37.1	65.4	40.8
Estonia	.	.	60.4	46.3	61.0	48.5	62.0	51.6
Cyprus	.	.	65.6	49.4	67.8	49.1	68.6	49.4
Latvia	.	.	57.5	36.0	58.6	36.9	60.4	41.7
Lithuania	.	.	59.3	40.6	57.5	38.9	59.9	41.6
Hungary	52.4	17.7	56.3	22.2	56.6	24.1	56.6	26.6
Malta	.	.	54.2	28.5	54.3	29.4	54.5	30.0
Poland	58.9	33.9	55.0	28.4	53.4	27.9	51.5	26.1
Slovenia	62.6	21.8	62.8	22.7	63.8	25.5	63.4	24.5
Slovak Republic	.	.	56.8	21.3	56.8	22.4	56.8	22.8

Source: Eurostat, Labor Force Survey, annual averages. OECD Outlook reports for the United States and Japan.
[a] In the United States, data is for 16–64. Cited in Increasing the employment of older workers and delaying the exit from the labor market. Commission of the European Communities. Brussels 3.3.2004. COM (2004) 146 Final.

is now possible to receive (reduced) unemployment benefits while working. Equally, there is an option to retire gradually by receiving a pension while working part-time. Also, people who defer claiming their pension receive an enhancement, though it has been argued that this will have little influence on behavior and has more to do with the government's desire to reduce social security expenditure. In addition, there have been efforts to promote greater demand for older workers via reductions in the employer's contribution to the social security system of those aged 45 or older. However, it has been pointed out that a workplace early retirement culture is persistent, which policy makers have been slow to address. Importantly, there has also been resistance from trade unions keen to protect rights to early retirement.

Labor force aging is high on the agenda of British policy makers, and there has been a gradual shift toward an extension of working life in the last 15 years. The government's manifest position is neatly summarized in its recent Pensions Green Paper, in which it sets out proposals for reform in the following areas:

- Help for those aged 50 and over and recipients of disability benefits to help them return to work
- Increases for those deferring claiming their state pension
- Allowing people to continue working for their employer while drawing their occupational pension
- Raising the age from which a pension may be taken from 50 to 55
- Changing public service pension scheme rules, for new members initially, to make an unreduced pension payable from 65 instead of 60.

Active Labor Market Policies

In France, the National Action Plan for Employment of 2003 mentions the desire of the government to embark on a national mobilization plan for workers aged over 55, access to training for those aged 45 or

Table 6 The Stockholm targets (2002)

	Employment rate of older workers in 2002			*Change in employment rate of older workers 1998–2002*		
	Total	*Men*	*Women*	*Total*	*Men*	*Women*
Belgium	26.6	36.1	17.5	3.7	3.9	3.5
Denmark	57.9	64.5	50.4	5.9	3.2	8.4
Germany	38.6	47.1	30.1	0.9	−0.1	1.8
Greece	39.7	56.0	24.4	0.7	0.2	1.0
Spain	39.7	58.6	22.0	4.6	6.0	3.2
France	34.8	39.3	30.6	6.5	6.8	6.2
Ireland	48.1	65.1	30.8	6.4	5.0	7.7
Italy	28.9	41.3	17.3	1.2	−0.1	2.3
Luxembourg	28.3	37.9	18.6	3.2	2.7	3.1
Netherlands	42.3	54.6	29.9	8.4	7.1	9.6
Austria	30.0	39.8	20.9	1.6	−0.7	3.8
Portugal	50.9	61.3	41.9	0.9	−2.2	3.6
Finland	47.8	48.5	47.2	11.6	10.1	13.1
Sweden	68.0	70.4	65.6	5.0	4.3	5.6
United Kingdom	53.5	62.6	44.7	4.5	3.5	5.5
EU15	**40.1**	**50.1**	**30.5**	**3.5**	**2.8**	**4.2**
EU25	**38.7**	**48.9**	**29.1**	**2.9**	**2.2**	**3.6**
Czech Republic	40.8	57.2	25.9	3.7	4.0	3.0
Estonia	51.6	58.4	46.5	1.4	−3.6	4.9
Cyprus	49.4	67.3	32.1	.	.	.
Latvia	41.7	50.5	35.2	5.4	2.4	7.7
Lithuania	41.6	51.5	34.1	1.1	−5.5	6.2
Hungary	26.6	36.7	18.5	9.3	9.7	8.9
Malta	30.3	50.4	11.8	.	.	.
Poland	26.1	34.5	18.9	−6.0	−7.0	−5.2
Slovenia	24.5	35.4	14.2	0.6	3.6	−1.9
Slovakia	22.8	39.1	9.5	0.0	0.0	0.1

Source: Eurostat, Labor Force Survey, annual averages.
Notes: . = not available; average exit age from the labor force: estimation for 2002 for EU15 and EU25, provisional data for PL; spring data for D, F, L, and CY. Average of quarter 2 and 4 in LV and LT. Data based on overall activity rates (not adjusted by gender since data by sex lack reliability due to the low sample size) for L, EE, CY, LV, LT, and SI.
Cited in Increasing the employment of older workers and delaying the exit from the labor market. Commission of the European Communities. Brussels 3.3.2004. COM (2004) 146 Final.

over, and the accreditation of prior learning. Additionally, long-term unemployed people aged 50 or over will be encouraged to find work through a relaxation of rules concerning combining income from employment with state benefits, wage subsidies are being enhanced to encourage employers to recruit more workers aged over 50, and older workers are to be encouraged to establish a small business. Furthermore, the government wishes to encourage small firms to extend the working lives of employees by establishing a service to assist them in long-term staff planning.

Nevertheless, the aging of the labor force does not appear to have a prominent place in policy debates. Added to this is public support for early retirement. For example, recently, one trade union that pressed an employer to retain older workers found this vetoed by its membership, who preferred early retirement. The reasons are partly cultural. For example, discrimination is a new concept, and previously, generous pre-retirement schemes have encouraged older workers to retire early.

In Germany, the potential of active labor market policies has recently come to the fore. The Hartz Modern Services in the Labor Market Commission, which was established in 2002 as the federal government's plan to modernize public employment services, makes specific mention of initiatives for older workers. On the supply side, the pay guarantee for older employees measure targets unemployed people aged 50 or over. It pays a grant of 50% of the net difference in pay between the job they had before becoming unemployed and their new job if the latter is of lower pay. On the demand side, employers who recruit workers aged 55 or over will be exempted from paying their share of the costs of employee development. In addition, an age limit imposed for part-time and temporary work beyond which such arrangements must be revised is being reduced from 58 to 52, with the intention of improving employment opportunities for older workers.

The Hungarian National Action Plan on Social Inclusion 2004–06 states that employers are being offered incentives to employ unemployed workers

Table 7 Trends in youth unemployment rates (percent of labor force age 15–24)

	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
Belgium	20.7	23.2	22.9	22.1	22.0	22.1	22.7	17.0	17.5	18.5	21.0	19.8
Denmark	12.8	10.2	9.6	9.7	7.7	7.3	8.8	7.0	8.4	7.9	9.9	8.2
Germany	15.0	15.6	14.9	15.6	16.2	15.0	12.7	10.6	12.8	14.2	14.7	15.1
Greece	26.8	27.7	28.5	31.0	30.8	30.1	31.9	29.2	28.2	26.8	26.8	26.9
Spain	38.4	40.2	37.8	37.2	34.6	31.3	25.8	22.9	21.7	22.3	22.7	22.1
France	27.1	28.6	27.0	28.5	28.4	25.6	23.4	20.1	19.4	20.0	21.1	22.0
Ireland	25.3	23.0	19.5	18.2	15.4	11.3	8.4	6.7	6.7	8.0	8.3	8.3
Italy	30.1	29.1	30.3	30.4	30.2	29.9	28.7	27.0	24.1	23.1	23.7	23.6
Luxembourg	5.2	7.1	7.2	8.2	7.9	6.9	6.9	7.2	7.3	8.3	11.4	12.9
Netherlands	10.6	10.9	11.4	11.1	9.1	7.6	6.8	5.7	4.5	5.0	6.3	8.0
Austria	6.3	5.7	5.6	6.3	6.7	6.4	5.4	5.3	5.8	6.7	8.1	9.7
Portugal	12.8	15.0	16.5	16.7	15.1	10.6	9.1	8.9	9.4	11.6	14.4	15.4
Finland	33.6	34.0	29.7	28.0	25.2	23.5	21.4	21.4	19.8	21.0	21.8	20.7
Sweden	22.0	22.0	19.1	20.5	20.6	16.1	12.3	10.5	10.9	11.9	13.4	16.3
United Kingdom	17.6	16.4	15.3	15.0	13.7	13.1	12.8	12.3	11.9	12.1	12.3	12.1
EU15	21.4	21.8	21.0	21.2	20.6	19.0	17.1	15.3	15.1	15.6	16.3	16.6
EU25	:	:	:	:	:	19.4	18.4	17.4	17.6	18.1	18.6	18.7
Czech Republic	:	:	:	:	:	12.8	17.7	17.8	17.3	16.9	18.6	21.1
Estonia	:	:	:	:	17.0	15.2	22.0	23.6	23.5	19.3	23.4	21.0
Cyprus	:	:	:	:	:	:	:	11.5	10.3	9.7	10.7	10.6
Latvia	:	:	:	:	:	26.8	23.6	21.4	23.1	23.9	17.9	19.0
Lithuania	:	:	:	:	:	25.5	26.4	30.6	30.8	23.8	26.9	19.9
Hungary	:	:	:	18.5	17.0	15.0	12.7	12.1	11.1	12.0	13.5	14.8
Malta	:	:	:	:	:	:	:	13.7	19.0	18.3	19.1	16.7
Poland	:	:	:	:	23.2	22.5	30.1	36.3	39.8	41.8	41.2	39.5
Slovenia	:	:	:	17.5	17.2	17.8	17.9	16.2	16.0	15.3	15.7	14.3
Slovakia	:	:	:	:	:	:	34.2	37.1	39.0	37.6	33.8	32.3

Source: Employment in Europe 2005, http://europa.eu.int/comm/employment_social/employment_analysis/employ_2005_fr.htm.

aged 50 years or over in the form of the removal of the obligation to pay health-care contributions.

In Italy, while active labor market programs have tended to favor younger workers, the recent Biagi Law provides for financial hiring incentives for disadvantaged groups, including people aged 50 or over. However, it has been observed that initiatives aimed at increasing access to employment have tended to have a youth focus. On the other hand, some Italian regions are promoting the employment of older people in community-based social solidarity services, with financial incentives sometimes available for employers.

In Spain in 1999, a pilot program was established that mainly targeted those aged over 40 and mixed vocational training with a period of public employment of between 6 and 12 months. Financial incentives are also available to older workers who participate in vocational training and accept assistance in finding a job. Nonetheless, it has been argued that the desire for an extension to working life and a reduction in the use of retirement pathways has not been sufficiently matched by measures to re-integrate older workers.

New Deal 50 plus is the flagship employment program for older workers in the UK. Implemented in April 2000, in its original form it offered employment advice to non-employed older people who had been claiming benefits for at least 6 months. The program was voluntary and open to people inactive on benefits as well as those registered as unemployed. It paid a cash employment credit on top of the wage directly to a person taking a job. The program has subsequently been revised and offers financial support when in work in the form of a working tax credit.

Since its launch, over 110 000 clients have moved into employment via the program, though this represents a minority of those eligible. The majority of employment credit claimants fell into the 50–54 age group (59%) and were previously claiming unemployment benefits (72%), while 7% were claiming disability or sickness-related benefits previously. Clients generally moved into full-time employment, although a large minority – almost one-third – moved into part-time employment. The proportion moving into self-employment increased over time.

Several evaluations have been undertaken. Key findings are as follows:

- The most useful element of the program was felt by clients to be the employment credit, providing an incentive to take low-paying work both in terms of level and reliability of income and reducing reservation wages.

- That this was not known about by the employer was also viewed as a positive by clients as it was felt this would not affect wages. This is particularly important, given that the new working tax credit is administered via the employer.
- However, there was evidence of deadweight, with in one study over half of those clients surveyed stating that they would have taken a job anyway without the employment credit, although it had encouraged almost two-thirds (63%) to take a job earlier than they otherwise would, and over two-fifths (43%) to stay in the job for longer than they might otherwise have done.
- However, it also tended to be most effective in geographical areas where there were low wages and low living costs.
- There was an issue regarding the sustainability of part-time employment, with those unable to increase their hours once the employment credit ended penalized, although the majority of clients tended to remain in employment once they had found it.
- A factor accounting for low take-up among disability-related benefit claimants may have been that financial gains from moving into paid employment could be small, and some would even be worse off.
- Clients tended to move into unskilled and low-paying service or manual jobs, despite the fact that many were previously in higher-paying or more skilled work.
- Self-employed clients tended to be positive about their experiences of claiming the employment credit, which was viewed as helpful in supporting them through the first year of their business.

Other research has considerd what happens to New Deal 50 plus clients once the employment credit ends. For the client group for whom there was 12 months of benefits data after their credit expiry, 84% were not claiming at the 52-week stage and 77% had not returned to claim at any stage during the 12 months following the end of their entitlement. Also, there was a difference in job retention between clients in general and those in receipt of the employment credit 6 months after their job starts. Employment credit claimants had a higher retention rate of 84%, compared to 70% for clients overall.

Tackling Age Discrimination: Regulation, Legislation and Collective Bargaining

As noted previously, the response of national policy makers to the Equal Treatment Directive has been piecemeal. In the Czech Republic an amendment to the labor code in 2001 outlawed any form of discrimination in employment, though recruitment agencies were excluded. Also, employers find ways round the law, and many are simply unaware of its existence. It is also important that, unusually, protection from unfair dismissal is accorded a worker even if they are entitled to receive a pension, though redundancy on grounds of age has still been common.

In France, the Labor Code was amended in 2001 to cover every aspect of working life in relation to discrimination, including age, and to adjust the burden of proof in discrimination cases, making it easier to pursue a case. This has not taken place with strong support from either employers or trade unions, and age discrimination does not feature in collective agreements. Also, the Labor Code had stipulated that an employer terminating the contract of a worker aged 50 and over must pay a special premium known as the Delalande contribution. This appeared to have a small effect on redundancy among older workers, and may in fact have discouraged their recruitment on the grounds that any subsequent layoff could prove costly to the company. The French National Action Plan for Employment of 2003 announced that the contribution would be relaxed for firms laying off employees recruited at age 46 or over.

The German federal government announced in 2006 that it would introduce a law proscribing age discrimination in employment. This belated development is partly due to the fact that the term age discrimination has not found much recognition among politicians or scientists. Furthermore, it may also be the result of strong opposition from employers' associations. By contrast, trade unions favor legislation, although views are split because early retirement is still seen by many as a socially acceptable way to leave the labor market. How the legislation will be overseen is unclear, with the government keen to minimize effects on business.

There are in fact already several legal provisions against age discrimination in the labor market in Germany. Federal employment agencies may only accept age limits for job advertisements from employers if these age limits can be justified. The Law on Labor Relations at the Workplace (*Betriebsverfassungsgesetz*, BVG) stipulates that both employers and works councils may not discriminate against workers on grounds of age and that works councils have the right to promote the employment of older workers. However, these provisions do not prevent these actors from negotiating early retirement.

Elsewhere, Italy addresses discrimination in employment on the grounds of age in its constitution,

which states a general principle of equality and non-discrimination. There are currently no plans to strengthen existing provision, though the recent Biagi Law has added age discrimination to prohibited acts for job recruitment agencies. In addition, the independent Department of Equal Opportunities helps individuals, informs policy and disseminates information to raise public awareness, though the issue of age discrimination has not been high on the agenda in discussions between employers and trade unions.

Similarly, issues of discrimination generally are only just coming on to the policy agenda in Hungary, with primary attention being given to disability, gender, and ethnicity, though measures to encourage firms to recruit older workers are also being implemented. With regard to the implementation of antidiscrimination legislation, transposition of the Equal Treatment Directive took place in May 2004. As far as specific provisions on age are concerned, progress had been made in relation to employment, where legislation and measures exist, and vocational training, where legislation exists. However, the Constitutional Court has decided that age restrictions in employment were not discriminative unless they were arbitrary. In terms of forced redundancy, compulsory retirement appears to be commonplace.

In Spain, primary legislation introduced in 2003 addresses discrimination in employment on various grounds, including age, and in terms of both direct and indirect discrimination. However, the trade unions would also like to see the principle of equality built into collective agreements, while the Spanish Confederation of Employers' Organizations (CEOE) considers that equal treatment with regard to age has already been progressed, with steps to eliminate incentives for early retirement and the ending of seniority pay supplements. CEOE also argues that legislation is not the best way to tackle discrimination, believing that it is burdensome for business, and preferring instead to see greater support for their members in terms of increasing access to employment for disadvantaged groups and workplace adaptation.

While the impact of the Equal Treatment Directive on European governments appears to have been varied, there are instances in which some have taken comprehensive approaches. Such examples include Ireland, the Netherlands, and the United Kingdom. Since the publishing of the directive there has been substantial debate in the UK around the form and content of legislation proscribing age discrimination. This will cover both direct and indirect discrimination in employment and vocational training. In exceptional circumstances, differential treatment according to age will be allowed, though employers must be able to justify this. The issue of a default retirement age being retained caused considerable controversy, with fierce public debate. Such an age (65) has been agreed on by government ministers, though this will be reviewed. A new Commission for Equality and Human Rights (CEHR) will oversee the legislation. In Ireland, where legislation concerning age has existed for some time now, cases brought have been few, and even when claimants have been successful, financial restitution has been modest. It is unlikely therefore that this legislation is sending strong signals regarding Irish society's opposition to age discrimination.

Awareness Raising

In several member states awareness-raising activities are being undertaken. In Germany there have been several actions. One project known as Demographic Change–Public Relations and Marketing Strategy aimed to increase public awareness of the impact of demographic change on employment and to distribute knowledge on effective age management among employers. The number of workshops, presentations, publications, media releases, and Internet/homepage launches indicate a strong outreach.

Since 2002, the Federal Ministry of Education and Research has funded a measure called Demography Initiative. This is led by three trade associations and funds 127 companies to implement policies on age management.

In April 2002, the federal government presented its overall strategy for sustainable development. It includes a subtheme called potential of older people in the economy and society and refers to so-called lighthouse projects run by companies that will promote the employability of older workers and encourage lifelong learning.

In 2003, the Federal Ministry for Economy and Labor implemented a public awareness and network campaign called Team Work for Germany. A public relations agency is providing information on role model companies that employ and recruit older workers.

In 2002, the federal government started the national initiative New Quality of Work. As part of this initiative, it is intended to create a network of occupational health professionals to foster health promotion for older workers and to raise awareness of good practice.

The British government launched its Code of Practice on Age Diversity in 1999, which has subsequently been subsumed under the banner Age Positive. This sets out principles of non-age-biased

employment practices. Included is guidance on the application of the principles and examples of best practice. Government-commissioned research found that a very small number of companies surveyed – 9% – had seen a copy of the code and a small number – 2% – had changed policies afterward.

Concluding Remarks

The issue of tackling age barriers in the labor market was not prioritized by European member states until recently. While there are emerging policy debates, policy making is in its infancy in most countries and barely exists at all in some. Countries such as Finland, the UK, the Netherlands, and recently Germany can be contrasted with this generally gloomy picture. It can also be observed that national policy making is sometimes contradictory, with initiatives on the integration of older workers co-existing with others that facilitate their removal. This points to the value of developing a policy framework on what constitutes active aging from an employment perspective.

It is also arguable whether age discrimination is recognized as an issue in many countries. Elsewhere, much work appears to have taken place. Why it has not been so prominent an issue in some countries is unclear. One explanation may be that the early exit of older workers has simply not been viewed as a problem in some countries where generously funded early retirement programs have cushioned the impact of job loss, or where high levels of youth unemployment may have focused public attention elsewhere.

On the other hand, age and work more generally is an issue of public debate in many countries. Early retirement as a policy tool is now widely discredited, with numerous reports pointing to deleterious effects on economies, employers, and individuals. Pension reform has been undertaken in member states, though the concerns are almost entirely fiscal, being about the sustainability of retirement income systems rather than equality of opportunity. Arguably, the present situation resembles that of the 1980s and 1990s in reverse. Then, older workers were viewed as a burden on European society, preventing the ascendancy of younger workers, with early retirement considered the solution. Now, along with an incessant rhetoric around dependency ratios, later retirement is viewed as the solution. Older workers are again being presented as a burden, though this time the conclusion is that they must take their place once more in the labor market. Whether this will benefit the vast majority of older workers is a matter of conjecture. Also, a background of persistently high levels of youth unemployment raises the question of whether policy making toward older workers will gain much traction.

Such a perspective does not sit well with the European Commission's stated desire for the promotion of active aging, except in the starkest and weakest of terms. Older workers are barely valued in their own right, their primary value coming from relieving the burden on younger people. They may be obliged to seek work against a background of labor market age discrimination. While some may benefit financially and socially from access to employment, others may find themselves at risk of long-term unemployment or in precarious employment.

Thus, the challenge for European policy makers will be to nurture the development of labor markets that provide meaningful opportunities for older workers, willing and able to make a contribution, while at the same time, those with skills deficits or other barriers that severely limit their employability have the opportunity to retire sooner or flexibly. However, this preliminary assessment suggests that they are some way short of achieving such a goal.

What can a non-European observer learn from these developments? First, Europe has put extending working lives at the center of its vision for economic growth. At the Lisbon European Council it set itself a strategic goal for the next decade of becoming the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion. As noted previously, targets on the employment of older workers are proving difficult to attain, pointing perhaps to difficulties in Europe of promoting policies aimed at increasing labor supply via an extension of the end of working lives at a time when some economies are struggling to grow and going against a deep-rooted early retirement culture. On the other hand, a vast range of initiatives across the member states may offer insights to policy makers elsewhere. Finally, scholarly debate on the aging of the European labor market flourishes, with major advances in our understanding of the nature of age discrimination and the role of public policy in both encouraging and overcoming age-related labor market barriers over the last 20 years.

See also: International Perspective on Gerontology; Retirement; Work and Employment: Individual.

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