September 19, 2003

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How do you get a computer virus?

Why do humans get "goosebumps" when they are cold, or under other circumstances?

How do neon lights work?

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Why can't a person tickle himself?

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How does a flame behave in zero gravity?

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How do you get a computer virus?

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Why do clouds turn gray before it rains?

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On average, how many degrees apart is any one person in the world from another?

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Do people lose their senses of smell and taste as they age?

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September 18, 2003

ASK THE EXPERTS : MEDICINE

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What causes insomnia?

Henry Olders, an assistant professor of psychiatry at McGill University in Montreal who conducts sleep research, explains.

Most people encounter sleep difficulties from time to time, often related to stress or pain. Many of these bouts get better without treatment. Unfortunately, in a significant proportion of the population, sleep problems turn into insomnia, which is defined as the chronic inability to fall asleep or to enjoy uninterrupted sleep. Some research suggests that attitudes about sleep, and the sleep patterns and behaviors prompted by these attitudes, make certain individuals vulnerable to chronic insomnia. The good news is that behavioral treatments are highly effective.

Just how big a problem is insomnia? The National Sleep Foundation surveyed more than a thousand adults in 2002. Thirty-five percent said that, every night or almost every night of the previous year, they had at least one out of these four symptoms: difficulty falling asleep, waking a lot during the night, waking up too early and not being able to get back to sleep, or waking up feeling unrefreshed. About 15 percent of the survey group reported taking either a prescription sleep medication or an over-the-counter sleep aid at least a few times a month. A study of the Canadian population found that 24 percent of people ages 15 and older reported insomnia, defined in this study as a "yes" response to the question "Do you regularly have trouble going to sleep or staying asleep?" Some of the factors associated with insomnia in this study included being female, being widowed or single, having a low education level, low income, unemployment, smoking, life stress, physical health problems, and pain or activity limitation. Although age did not seem to be a factor in this survey, other studies have shown that insomnia increases with age. For example, 4 percent of a sample of older European adolescents met criteria for insomnia disorder as defined by the Diagnostic and Statistical Manual, 4th edition (DSM-IV) of the American Psychiatric Association. Compare this to a group of 330 elderly patients in a family practice, in which 57 percent met criteria for DSM-IIIR insomnia disorder. What's worse, insomnia is not a benign problem. Difficulty falling asleep or staying asleep is associated with an increased risk of dying in the elderly. Many elderly insomniacs take naps during the day; in addition to making insomnia worse, naps are related to higher mortality in this age group. More >>

More Questions

Do people lose their senses of smell and taste as they age?

Why do some people get more cavities than others do?

How can you live without one of your kidneys?

How do you get laryngitis?

Why does your stomach growl when you are hungry?

Why do certain drugs make the skin more sensitive to sun?

Why don't our digestive acids corrode our stomach linings?

How does someone get two different-colored eyes?

What makes the sound when we crack our knuckles?

What happens when you get a sunburn?

What are the effects of the drug Ecstasy?

If a used needle can transmit HIV, why can't a mosquito?

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What is a concussion?

Do vitamins in pills differ from those in food?

Do the telomeres in cancer cells shrink?

There are many kinds of cancer, so why is there no heart cancer?

When was malaria first discovered and by whom? How is the disease transmitted? What are its effects?

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ASK THE EXPERTS : MEDICINE

Do people lose their senses of smell and taste as they age?

N. Sly
Windsor, Australia

Charles J. Wysocki, a neuroscientist at the Monell Chemical Senses Center in Philadelphia who studies individual variation in olfaction and chemical irritation, provides the following explanation.

As people age they often complain about decreases--or even losses--in their abilities to taste a superb meal or appreciate a fine beverage. When people eat a meal, however, they often confuse or combine information from the tongue and mouth (the sense of taste, which uses three nerves to send information to the brain) with what is happening in the nose (the sense of smell, which utilizes a different nerve input).

It's easy to demonstrate this confusion. Take a handful of jellybeans of different flavors into your hand and move them about while your eyes are closed. With your other free hand, pinch your nose closed. Now pop one of the jellybeans into your mouth and chew, without letting go of your nose. Can you tell what flavor went into your mouth? Probably not, but you most likely experienced the sweetness of the jellybean. Now let go of your nose. Voila--the flavor makes its obvious appearance.

This phenomenon occurs because smell provides the information about the flavor. Chemicals from the jellybean are inhaled through the mouth and exhaled through the nose, where they interact with special receptor cells providing information about smell. It's the reverse process that one experiences downwind from a pig farm or chocolate factory. From these sources, chemicals (termed odorants) are carried on the wind, perhaps for tens of miles, and enter the nose during an inhalation. These odorants then interact with the receptor cells and initiate a series of events that are interpreted by the brain as a smell.

Estimates for different types of odorant molecules vary, but there are most likely more than tens of thousands of them. Taste, on the other hand, is limited to sweet, sour, bitter, salty and umami (the taste of monosodium glutamate (MSG)). With advancing age there is an associated diminution in sensitivity of the sense of smell--much more so than a decrease in sensitivity to tastes. This perception may result from an accumulated loss of sensory cells in the nose (perhaps as much as two thirds of the original population of 10 million).

A different nerve provides information about spiciness. Here, too, with advancing age there is a decrease in sensitivity to the sting in hot peppers or the bite in the nose from a dollop of horseradish. As a result, the elderly are in general less sensitive than young people to the overall perception of the food they eat and may complain that the "taste" isn't the same as it used to be. There are exceptions, however: some 90-year-olds may be more sensitive to smells than some 20-year-olds.

Answer originally posted February 25, 2002.

Answer posted on April 28, 2003

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ASK THE EXPERTS : MEDICINE

Why do some people get more cavities than others do?

Matthew
Astoria, NY

Joel Berg, president of the American Academy of Pediatric Dentistry Foundation and VP of Clinical Affairs for Philips Oral Healthcare, offers this explanation:

Dental caries is the most prevalent infectious disease in humans, affecting 97 percent of the population in their lifetime. The result of the disease process known as dental caries, getting cavities is a complex and multifactorial scenario. Caries is biofilm-induced, acid demineralization of the teeth, and it requires the right combination of conditions in order to progress. When tooth enamel is subjected to a pH lower than 5.5, it begins to demineralize. Above this so-called critical pH, a mitigating repair process—remineralization—can occur. Remineralization is in turn influenced by the presence of salivary minerals, available fluoride ion and salivary flow rate. It is when the "tug of war" balance leans toward the demineralization side over a period of time without commensurate and compensatory remineralization that the caries process can progress to the point of cavitation and create a visible cavity. This cavity must then be restored using operative dentistry procedures, better known as fillings.

All bacterial biofilms are not alike, however. Although *Mutans streptococci* and other species have been implicated as primary culprits in causing caries, some people who are infected with these species of bugs don't get cavities. Genotypically different strains of the same bugs exhibit varying levels of cariogenicity. Therefore, it's not just the quantity of plaque biofilm present, but the specific strain with which one is infected that is important in predicting who might get cavities.

Diet is another contributing factor to cavity susceptibility. It seems clear that caries-causing organisms prefer sugars—specifically sucrose—as a primary energy source. The metabolism of this sugar into lactic acid causes cavities. Going back to the tug of war scenario between demineralization and remineralization, one can quickly surmise that it is the frequency of sugar exposure in one's diet—not the quantity—that predisposes caries to progressing in an effectively unmitigated manner. Therefore, controlling the number of sugar exposures (consolidating sugar-containing-sweet-eating episodes to mealtimes, for instance) aids the remineralization side of the equation.

A third important factor is salivary flow and composition. Simply said, the more saliva present in the mouth, the better "natural debridement" occurs, cleaning teeth surfaces of caries-causing organisms and the acids they produce. If the saliva is too viscous, however, it may not exhibit the right flow properties to effectively clean affected areas.

Oral hygiene is also an important contributing factor. Our dental professionals continually admonish us to "brush and floss." These oral care regimens must be performed religiously at least daily, and preferably twice a day, in order to be entirely effective. These activities reduce the levels of "local factors" (biofilms and their nutrient warehouses), which helps keep caries under control.

Another factor contributing to the difference in caries manifestation and progression in different people is tooth morphology. Deep grooves on the surface of teeth (molars in particular) make them susceptible to caries, because they entrap biofilms easily and make it harder to remove them.

These are just some of the many factors that contribute to caries progression and ultimately cavities. The diet, hygiene and fluoride regimens are controllable. The strain of bacterial infection, salivary flow and morphology of teeth are less controllable. Regardless, one can see

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why some people get cavities and others don't.

Answer posted on July 01, 2002

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ASK THE EXPERTS : MEDICINE

How can you live without one of your kidneys?

D. Kered

Birmingham, Ala.

Mark A.W. Andrews, associate professor of physiology at the Lake Erie College of Osteopathic Medicine, provides the following explanation:

This is an excellent question, especially because kidney disease and kidney transplants are so common (approximately 10,000 to 15,000 Americans receive kidney transplants each year). Most humans are born with two kidneys as the functional components of what is called the renal system, which also includes two ureters, a bladder and a urethra. The kidneys have many functions, including regulating blood pressure, producing red blood cells, activating vitamin D and producing some glucose. Most evidently, however, the kidneys filter body fluids via the bloodstream to regulate and optimize their amount, composition, pH and osmotic pressure. Excess water, electrolytes, nitrogen and other wastes get excreted as urine. These functions maintain and optimize the "milieu interieur" (internal environment) of the body--the fluids in which our cells live.

Life is incompatible with a lack of kidney function (though hemodialysis can act as a substitute). But unlike the case with most other organs, we are born with an overabundant--or overengineered--kidney capacity. Indeed, a single kidney with only 75 percent of its functional capacity can sustain life very well.

This overengineering supplies us with 1.2 million of the basic functional filtering element, the microscopic nephron, in each kidney. Nephrons are tiny tubes that filter the blood plasma, adjust and then return optimized fluid to the body. Under most conditions, though totaling only a few pounds, the kidneys receive about 20 percent of all the blood pumped from the heart. Each day, about 120 liters of fluid and particles enter into the nephron to be filtered.

If only one kidney is present, that kidney can adjust to filter as much as two kidneys would normally. In such a situation, the nephrons compensate individually by increasing in size--a process known as hypertrophy--to handle the extra load. This happens with no adverse effects, even over years. In fact, if one functional kidney is missing from birth, the other kidney can grow to reach a size similar to the combined weight of two kidneys (about one pound).

The kidneys filter this large amount of fluid on a daily basis because nephrons are fairly indiscriminant filters, removing all contents from the blood except for larger proteins and cells. The nephrons, however, are extremely accomplished in processing the filtrate and substances critical to survival--such as water, glucose, amino acids and electrolytes, which are actively reabsorbed into the blood. The water and waste (including urea and creatinine, acids, bases, toxins and drug metabolites) that remain in the nephrons become urine.

In addition to being able to support life with only one kidney, the renal system has other safeguards. Although nephrons stop functioning at a rate of 1 percent per year after 40 years of age, the remaining nephrons tend to enlarge and fully compensate for this demise. Evidence strongly suggests that living kidney donors are highly unlikely to develop significant long-term detrimental effects to their health, as illustrated by donors whose renal function has been assessed for up to 30 years following donation. The main problems with donors are rare instances of complications having to do with the surgery, not the lack of the kidney.

Answer posted on April 22, 2002

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September 18, 2003

ASK THE EXPERTS : MEDICINE

How do you get laryngitis?

K.Duncan
Miami, Fla.

***Scientific American* spoke with Rebecca N. Gaughan, an ear, nose and throat (ENT) doctor in private practice in Olathe, Kan., to learn the answer. An edited transcript follows.**

SA: What causes laryngitis?

RG: The most common form of laryngitis is usually caused by a virus, just like a cold is caused by a virus. So you can catch it from other people.

SA: Is it different from straining your voice by using it too much?

RG: There are different causes of laryngitis. Most people think of laryngitis as a cold-like illness. But laryngitis can also be caused by straining the voice, as in yelling at a football game or forcing oneself to speak very loudly in front of a group without a microphone. Laryngitis itself is just the swelling of the vocal chords, which are part of the larynx. The key is, if you have hoarseness or an unusual voice for more than three to four weeks, then you need to get your voice box checked by a physician who can look at your vocal chords. It could be something more serious, even cancer.

SA: What would the treatment be if you were diagnosed with the viral form?

RG: The treatment for the viral form is similar to the treatment for the common cold. Drink noncaffeinated fluids, rest, perhaps use a humidifier and, most important, do not strain your voice. Don't whisper, don't raise your voice or talk for long periods of time. Resting your voice helps. Unfortunately, most people tend to keep talking and forcing their voice, causing more strain and hoarseness.

SA: So it's bad to whisper if you have laryngitis?

RG: Whispering is one of the worst things you can do because it's like yelling. It strains, or pulls, on the vocal chords. Instead you want to try to take a deep breath and then exhale as you talk. Try to relax your voice and not strain it.

SA: What is the effect of caffeine on your vocal chords when you have laryngitis?

RG: Caffeine dehydrates you. You want to drink noncaffeinated fluids to hydrate yourself so the mucus in your throat and around your voice box stays watery and protects your vocal chords. If you are not getting enough water, or you drink a lot of caffeinated fluids, you will make thicker, drier mucus that is less lubricating.

SA: How long might someone expect to show symptoms of laryngitis?

RG: Anywhere from five to 14 days. If it's lasting longer than 14 days, you have to think that there's something else, other than a virus, causing the hoarseness.

SA: What exactly happens to the vocal chords during a bout of laryngitis?

RG: The vocal chords become swollen. They are dry, irritated and swollen, and your voice

doesn't sound normal. Instead you have a kind of breathy, whispery voice.

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SA: Is laryngitis more common during the winter?

RG: Yes, laryngitis is more common in the peak flu and cold season, usually November, December and January.

SA: In general, how common is laryngitis?

RG: Much fewer people get laryngitis than colds. An average adult gets up to three colds a year, and a three-year-old child averages eight colds a year. In contrast, most adults get an average of one bout of laryngitis a year or one every couple of years.

SA: What about the less common types of laryngitis?

RG: Sinus drainage or a severe cough can also cause laryngitis. Coughing forces the vocal chords together and can cause swelling and irritation. Reflux, or acid entering the throat from the stomach, is another possible cause of throat clearing and laryngitis. Laryngitis from acid reflux needs to be evaluated by an ENT doctor.

The key thing is that if it's not better in three or four weeks, see someone who can actually look at your vocal chords in order to evaluate them.

Answer posted on February 11, 2002

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Titanium Metals Corporation (TIMET)
Alchemy of a Supermetal
Titanium often ranks as the engineer's first choice as a structural material for jet aircraft, racecars, oil-drilling equipment or prosthetic body implants, but the high cost of wresting the pure metal from ore translates into expensive products. Titanium Metals Corporation is one of a number of companies working on potentially low-cost production routes for titanium and its alloys.

Staking Claims

Intellectual Property Issues in review

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ASK THE EXPERTS : MEDICINE

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Is there any evidence that microwaving food alters its composition or has any detrimental effects on humans or animals?

Anuradha Prakash, assistant professor in the Department of Food Science and Nutrition at Chapman University, offers this explanation:

There is no evidence that eating microwaved foods is detrimental to humans or animals. Microwaves are low-energy waves that, like visible light, fall within the electromagnetic spectrum. Like all electromagnetic waves, they are composed of photons, but the photons in microwaves have so little energy that they are unable to cause chemical changes in the molecules they encounter--including those in food. They are non-ionizing waves and do not leave a residue. More >>

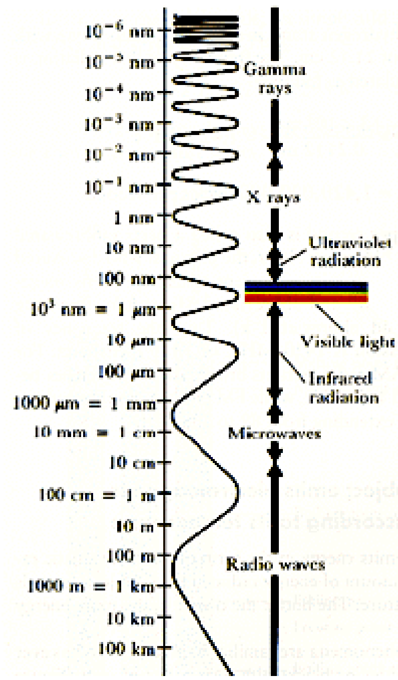

Image: UNIVERSITY OF OREGON

ELECTROMAGNETIC SPECTRUM. Radiation waves within this spectrum--including radio waves, microwave, infrared light, visible light, ultraviolet light, x-rays and gamma rays--differ only in terms of wavelength, which is directly related to the amount of energy they carry. The shorter the wavelength, the higher the energy. Microwaves have relatively long wavelengths and, as a result, little energy.

More Questions

What are the effects of alcohol on the brain?

How do MRIs detect medical problems?

What happens to the body and brain of individuals with schizophrenia?

What causes strokes?

Can asthma be cured? What are the latest treatments?

What happens to the brain during a concussion?

What is thalassemia?

Can a pocket laser damage the eye?

Is it true that surgeons are now using glues and adhesives to seal incisions? What are these materials?

Why do our eyes have a peak spectral response of only about 550 nanometers?

Do contact lenses protect the eye against toxic or hazardous chemical vapors or do they selectively absorb such chemicals?

Is it true that creativity resides in the right hemisphere of the brain?

What is a headache?

What progress is being made toward growing replacement human organs and tissues?

What is the function of the various brainwaves?

Why do we get the flu most often in the winter? Are viruses more virulent in cold weather?

For which diseases or conditions is umbilical cord blood stem-cell therapy most effective?

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What is the difference between "good" cholesterol and "bad" cholesterol? Why do we have cholesterol, anyway?

What is the current thinking regarding the relation between salt intake and hypertension?

ASK THE EXPERTS : MEDICINE

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Can you explain AIDS and how it affects the immune system? How does HIV become AIDS?

William Chris Woodward, Medical Director at Bornemann Internal Medicine in Reading, Pa., relays the following description:

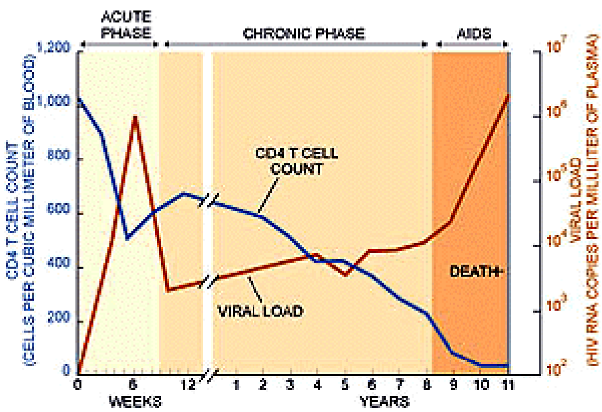

Image: *SCIENTIFIC AMERICAN*

HIV INFECTION begins with a sharp rise of virus in the blood *(orange line)* and a consequent drop in CD4 T cells *(blue line).* The immune system soon recovers somewhat, however, and keeps HIV levels fairly steady for several years. Eventually, though, the virus gains the upper hand. AIDS is diagnosed when the CD4 T cell level drops below 200 cells per cubic millimeter of blood or when opportunistic infections arise.

The acquired immune deficiency syndrome (AIDS) was first recognized in the early 1980s. AIDS is caused by the human immunodeficiency virus (HIV) and is spread through the exchange of body fluids (sexual encounters, sharing needles, blood transfusions). Recent research suggests the virus "jumped" to humans from a West African subspecies of chimpanzee *(Pan troglodytes troglodytes)* intermittently decades or even centuries ago. The World Health Organization (WHO) estimates that millions are infected with HIV worldwide and that it is the most devastating epidemic since the influenza pandemic of 1918. There are some predictions that HIV will not be controlled until the middle of the next century and that it may continue to devastate developing countries for the next 100 years. More >>

More Questions

What do we know about the nature of attention-deficit disorder (ADD)? And why does the drug Ritalin seem to reduce the symptoms of ADD?

What is the function of the human appendix? Did it once have a purpose that has since been lost?

What is known about the nature, cause and possible treatment of the disease scleroderma?

What is a prion? Specifically, what is known about the molecular structure of prions and how they cause infections such as Creutzfeldt-Jakob disease?

What function does Immunoglobulin E serve? Scientists seem to have identified only the troubles that result from its presence (such as allergies and anaphylaxis) rather than any positive value attributable to it.

How close are we to developing an effective gene therapy for treating cancer? Are there any other ways to strike at the fundamental mechanisms that trigger growth of cancer cells?

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If a diet of caloric restriction can extend the life span of laboratory rats, then does the lifestyle of an athlete, who burns calories at a rapid rate, hasten the aging process?

Is there a biochemical test that accurately diagnoses bipolar disorder? I heard on the radio today that millions of people in the U.S. have bipolar disorder and that 75 per cent of them are undiagnosed and untreated.

Is there any conclusive medical evidence on the health benefits (if any) of circumcision? I've read of an increased incidence of vaginal cancer and venereal disease among the wives of noncircumcised men, but this information did not come from a reliable scientific source.

How do scientists make artificial blood? How effective is it compared with the real thing?

If the cells of our skin are replaced regularly, why do scars and tattoos persist indefinitely?

Is there any conclusive research linking estrogen mimickers (such as organochlorines) to breast cancer or to other health effects? I have heard a great deal of disagreement regarding the danger of these compounds.

Dysthymia, a disorder related to depression, seems to be diagnosed increasingly often. Is it a newly recognized condition? What do we understand about its cause and treatment?

What is known about the nature and diagnosis of Tourette's syndrome? Do we know what causes it, and can it ever be cured?

What causes the noise we hear when we crack our knuckles or pop other joints? I've read that the sound comes from the release of gas bubbles. If so, what sort of gas bubbles are they, and how can releasing them possibly make so much noise?

Is it possible to engineer viruses to perform specific tasks within a human host--that is, to create viruses that are beneficial rather than detrimental to human health?

What do we know about the cause of Werner syndrome and progeria, the disease that leads to premature aging in children?

Do we know anything about the kinds of diseases that affected dinosaurs?

Has anyone ever done scientific experiments on the effects of human isolation over long periods, months or even years? Such information would seem to be important for manned missions to Mars or beyond.

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September 18, 2003

ASK THE EXPERTS : MEDICINE

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What causes macular degeneration in the eyes? Have there been any advances in curing this condition?

Edwin M. Stone, M.D., Ph.D., Director of the Center for Macular Degeneration and the Molecular Ophthalmology Laboratory at the University of Iowa, provided this medical outline:

The term macular degeneration refers to a group of disorders that affect the central portion of the retina and, as a result, the center of the field of vision. The most common forms of this disease usually affect patients over the age of 65 and are collectively the most frequent cause of legal blindness in developed countries. More >>

More Questions

What is the current understanding regarding the health effects of low-frequency electromagnetic radiation, such as that from high-voltage power transmission lines?

Antibiotics have been around for years, so why is it only recently that antibiotic-resistant bacteria have become the focus of attention and alarm? Also, why are resistant strains especially likely to arise if a patient doesn't complete a course of antibiotic therapy? It seems counterintuitive.

Dysthymia, a disorder related to depression, seems to be diagnosed increasingly often. Is it a newly recognized condition? What do we understand about its cause and treatment?

Is there any proof that Alzheimer's disease is related to exposure to aluminum--for instance, by using aluminum frying pans?

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ASK THE EXPERTS : MEDICINE

What do we know about the nature of attention-deficit disorder (ADD)? And why does the drug Ritalin seem to reduce the symptoms of ADD?

Shauna Rae Brown

Chandler,Ariz.

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Madelyn Griffith-Haynie founded and manages the Optimal Functioning Institute in New York City; she also publishes the Optimal Functioning Newsletter, an e-zine combining coaching viewpoints and ADD issues, and develops content for the Coach Web site. She is herself ADD. Griffith-Haynie replies:

"I'd like to start by reviewing some facts about ADD. ADD has been medically described since 1902. There is little agreement about what causes it, how to diagnose it and how to treat it. According to some studies, ADD affects as many as 10 million Americans, many of them adults, and approximately 4 percent of school-age children. Males are more likely to exhibit associated hyperactivity (attention-deficit/hyperactivity disorder, or AD/HD); that hyperactivity may help explain why three times as many males as females have been diagnosed with ADD. Depending on whose statistics you believe, about 80 percent of children and 50 percent of adults improve with medications.

"Now, some myths. Myth: ADD disappears during puberty. Myth: Physical hyperactivity must be present to confirm an AD/HD diagnosis. Myth: Positive response to medication is confirmation of diagnosis. Myth: Distractibility is responsive to will. Myth: ADD can be prevented with good prenatal care. Myth: Good parenting can prevent much of the acting out in ADD children. Myth: By extension, poor parenting is responsible for behavior problems in ADD children. Myth: Parents who medicate their children are trying to make their own lives easier. Myth: ADD medication removes will and creativity.

"The defining feature of ADD, as the name indicates, is a problem with 'attending,' which may be defined as focusing selectively on an intended stimulus, sustaining that focus and shifting it at will. The following characteristics are the result of disordered attending: difficulty focusing attention; poor organization and task completion; low stress tolerance; hyperactivity; impulsivity; mood swings; difficulty with time management; trouble with transitions; and perfectionism, or black-and-white thinking.

"ADD has been medically described for almost 100 years as minimal brain damage (MBD), hyperkinetic reaction of childhood (HRC), attention-deficit disorder (ADD) and, most recently, attention-deficit/hyperactivity disorder (AD/HD). The consistent recognition of ADD began when the first amphetamine studies were published in l988, just as child psychiatry really differentiated itself from its origins in adult psychiatry.

"Motor hyperactivity dominated early thinking about ADD, both because it was such a dramatic problem and because it seemed to respond so markedly to the use of stimulants. But because motor hyperactivity tends to lessen with age, the idea that ADD was primarily a childhood disorder--outgrown when the hyperactivity was no longer overt--became popular, fanned by ADD's placement in the child psychiatry section of the *Diagnostic and Statistical Manual* (DSM). We now know that ADD persists beyond childhood and that overt symptoms of hyperactivity are not necessarily present in every ADDer. ADDers can appear 'driven' or 'dreamy/spacey,' hyperactive or inattentive, or a combination of both.

"Although everyone gets distracted sometimes, an ADD diagnosis is one of degree and persistence. An individual must present symptoms severe enough to be clearly maladaptive and inconsistent with his or her developmental level and to have caused some evident impairments since childhood in at least two settings (for instance, at home and at work or school). There is no blood test, CT scan or other fully researched quantitative measure of ADD, so diagnosis relies heavily on anecdotal evidence. We know the disorder only by the prevalence, persistence and degree of disability caused by its presenting symptoms.

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"The efficacy of Ritalin in treating ADD may seem surprising given that Ritalin is a stimulant medication. If ADDers seem overstimulated, why would a stimulant calm them down? The answer seems to be that some neurons are working overtime while others are underfunctioning in a person with ADD. Stimulating the latter actually brings about a balance.

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Answer posted on October 21, 1999

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ADDinformation from Internet Mental Health

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ASK THE EXPERTS : MEDICINE

Has anyone ever done scientific experiments on the effects of human isolation over long periods, months or even years? Such information would seem to be important for manned missions to Mars or beyond.

Erik Paesel
Los Angeles, Calif.

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Nick Kanas, a professor of psychiatry at the University of California, San Francisco, replies:

"You raise a very interesting question. I have reviewed more than 60 reports from studies conducted in space-analogue environments, such as in Antarctica, submarines, land-based and submersible simulators, and from studies of hypodynamia, or confined bed-rest. Many of these have lasted months to a year or more (Antarctic missions and Biosphere 2, for example). My colleagues and I have called into question the salience of such analogue studies for manned space missions, however, especially for issues involving the psychosocial functioning of crew members. For instance, there is some evidence that crew anxiety is expressed differently during Antarctic missions than during hyperbaric (high-pressure) chamber studies because of the differing psychological meanings and degree of danger in these two isolated environments.

"The anecdotal literature (drawn from briefings and reports, for instance) suggests that groups of people working under long-term isolated conditions go through phases of tension and cohesion. For example, the Russians have found that depression-like 'asthenic reactions' are most likely to occur during the long, monotonous middle part of their space missions. Crew tension also seems to be related to crew heterogeneity, as reflected by such factors as gender, cultural background, native language and level of career motivation. People in isolated groups sometimes displace their intra-group tension and anger to the monitoring people on the outside. Finally, in terms of leadership, both task and supportive leadership roles are important for mission success, depending upon the work demands and the degree of monotony experienced by the crew members.

"Despite the presence of such anecdotal reports, I am not aware of any reports involving scientific studies of psychosocial issues during long-duration manned U.S. and Russian space missions. In a new study funded by NASA, my colleagues and I are studying crew-member and mission-control tension, cohesion and leadership issues that arise during five NASA/Mir space missions, each lasting four to six months. We hope to gather data that will be of use in training and supporting future crews involved with the international space station and perhaps with a future mission to Mars."

JoAnna Wood of the Psychology and Behavior Laboratory at the National Aeronautics and Space Administration's Johnson Space Center offers the following information:

"There has been a fair amount of research on this topic conducted in the Arctic and Antarctic, two areas where isolation is a common occurrence, as well as other extreme environments, such as naval submarines. These studies tend to suffer from the same methodological limitations, however. They may show the gross psychological changes that took place between the time when people entered an isolated environment and when they returned (subclinical depression being the most common symptom), but they do not generally document the detailed fluctuations of mental state that occur during isolation.

"Now, with the advent of notebook computers and refined statistical analysis techniques, we are getting a much clearer picture of what happens to people in long-duration isolation. These data come from various sources. For a little over three years, we have been involved in a collaborative project between the Johnson Space Center and the Australian government's Antarctic Division, in which we study Australian expeditioners while they are stationed in small groups at Antarctic research bases for periods up to 15 months, as well as two 100-day, six-person Antarctic traverses. We share advice and recommendations. My group has also collected information from an Antarctic traverse conducted by a French and Italian group.

"Here at the Johnson Space Center, we have just started collecting data from small crews that spend time in the Life Support Integration Facility. This facility is used for engineering and testing the kinds of life-support systems that would be used on long-duration space missions, such as a manned mission to Mars (including closed-loop systems that recycle water and air). We are studying the people who work on this project while they live with their equipment inside the facility for 30 to 60 days at a time. This sort of study is very important because it allows a comparison with the Antarctic crews. We can begin to explore variations in the motivations of the people in isolated environments and of the stresses they encounter in the different environments.

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Answer posted on October 21, 1999

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ASK THE EXPERTS : MEDICINE

What are the effects of alcohol on the brain?

Bimpe Aderoju,

Annandale, Virginia

Anthony Dekker D.O., Director of Ambulatory Care and Community Health at Phoenix Indian Medical Center, replies:

The product of the oldest chemical reaction studied by man<, alcohol, continues to challenge researchers. Since the original work on alcohol's neurological effects in the early 20th century, new theories have regularly emerged. What we have learned is that alcohol is a sedative-hypnotic in the acute intoxication phase for most patients. But it diminishes the quality of sleep. Individuals with sleep apnea often experience longer and more severe apneic episodes and hypoxia, or oxygen deprivation, after drinking alcohol.

A BRAIN ON BOOZE

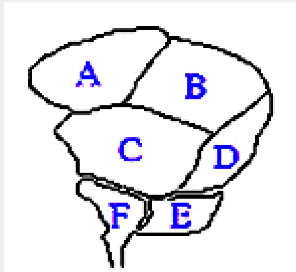

Image: MOUNT HOLYOKE COLLEGE

UNDER THE INFLUENCE of alcohol, the brain experiences impairments in the regions shown: **Frontal Lobe (A)** Loss of reason, caution, inhibitions, sociability, talkativeness and intelligence **Parietal Lobe (B)** Loss of fine motor skills, slower reaction time, shaking **Temporal Lobe (C)** Slurred speech, impaired hearing **Occipital Lobe (D)** Blurred vision, poor distance judgement **Cerebellum (E)** Lack of muscle coordination and balance **Brain Stem (F)** Loss of vital functions

In other individuals, though, alcohol may act as a stimulant. Indeed, its association with violent and self-abusive behavior is well documented. At intoxicating levels, alcohol is a vasodilator (it causes blood vessels to relax and widen), but at even higher levels, it becomes a vasoconstrictor, shrinking the vessels and increasing blood pressure, exacerbating such conditions as migraine headaches and frostbite. Researchers have also thoroughly documented the effects of alcohol on the developing fetus. Approximately one third of all babies born to alcoholic mothers will develop Fetal Alcohol Syndrome or Effects (FAS or FAE), causing central nervous system (CNS) dysfunctions including Attention Deficit Disorder (ADD) and impaired IQ. There are also growth and facial abnormalities associated with these infants.

In the early 1900s, H. Meyer and Charles Ernest Overton originally theorized that the effect of alcohol was achieved by altering the lipid environment of cell membranes. This theory, however, requires much higher concentrations of alcohol than are clinically observed. A recent theory, supported by several researchers, pins alcohol's effect on voltage and ligand-gated ion channels that control neuronal activity. Two distinct ligand-gated channels have been identified, inhibitory ones (GABA receptors and strychnine-sensitive glycine receptors) and excitatory ones (N-methyl-D-aspartate (NMDA) and non-NMDA glutamate-activated channels and the 5HT3 subtype of serotonin receptors).

The inhibitory aspect occurs due to a hyperpolarization of neurons, secondary to an influx of chloride ions. The neuron becomes less likely to achieve the threshold membrane potential. The excitatory receptor is dependent on the NMDA and non-NMDA glutamate receptors that control the influx of sodium and calcium, which bind to endogenous neurotransmitters (glutamate or aspartate) and depolarize the neuronal membrane. The NMDA receptor seems to have a high permiability to calcium, which acts as a catalyst to several intracellular events.

Chronic exposure to alcohol seems to alter the NMDA receptors and this may play a role in the clinical symptoms of alcohol withdrawal. In vitro studies have demonstrated an increase in the binding sites for MK801 (dizocilpine) in neurons chronically exposed to alcohol. This rise may account for the acclimation process, in which greater concentrations of alcohol are needed to cause experimental and clinical symptoms of intoxication. NMDA can cause seizure activity. Mice that have been exposed to chronically elevated levels of alcohol reveal increased numbers of NMDA receptors and NMDA related seizure activity. The NMDA antagonist MK801 has been shown to decrease the severity of seizures in these mice during withdrawal. Through a complex process of cell membrane ion pumps and neurotransmitter stimulation, the multi-faceted effects of alcohol and alcohol withdrawal are becoming better understood.

Answer posted on July 26, 1999

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ASK THE EXPERTS : MEDICINE

How do MRIs detect medical problems?

Ido Horresh,

Jerusalem

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Robert Gerstman D.O., a member of the American Osteopathic Association, provides the following explanation. Dr. Gerstman, who specializes in psychiatry, is board certified by the American Osteopathic Board of Neurology and Psychiatry and the American Board of Psychiatry and Neurology.

Before Magnetic Resonance Imaging (MRI) entered the clinical arena in 1982, the only way to get any sort of 3-D representation of the human body was by using Computerized Axial Tomography, otherwise known as CAT or CT scans. Although CT works well in certain contexts, it has limitations. It exposes patients to radiation and only shows the body on its axial (top to bottom) plane.

Image: THE WHOLE BRAIN ATLAS

MRI IMAGES reveal many parts of the body that were previously only seen during autopsy. This picture depicts brain changes associated with Huntington's Chorea.

In contrast, MRI does not rely on the absorption of x-rays. It is based instead on Nuclear Magnetic Resonance (NMR). When MRI was first introduced in research, it was actually called NMR. That name, though, scared many people who incorrectly assumed that the technique would expose them to nuclear radiation. In fact, the 'N' of NMR represents atomic nuclei and how they spin, not nuclear radiation.

The basic physics involved is as follows: When atoms are placed in a magnetic field, the odd-numbered atoms (those having an unequal number of protons and neutrons, such as hydrogen) align within this field. In other words, their axes of rotation all point the same way. Hydrogen is the most abundant odd-numbered atom in the body, but all odd-numbered atoms are subject to this alignment process. When these atoms are then exposed to a brief interruption of the magnetic field (commonly referred to as a pulse), they shift away from the magnetic field. After the pulse is lifted, the atoms realign, emitting a radiofrequency signal. Scanners in an MRI machine collect all the signals from the individual nuclei and, with the help of computer analysis, use that information to create a series of dimensional images.

Unlike CT, MRI can show pictures along many planes--the axial plane, the saggital plane (side to side) and the coronal plane (front to back)--enabling physicians to see images that were previously impossible to visualize except during autopsy. Of clinical significance, using different pulse signals results in different image types. The three most commonly used types are termed T1, T2 and proton density.

T1 is a short, fast pulse that makes fat tissue appear bright and cerebral spinal fluid (CSF) dark. T1 images look like CT images and are more focused than the other MRI image types. T1 allows for the overall visualization of structures in the body--a view that can be enhanced by using a contrast medium. In the same way that iodine can be used in CT scans to stain blood vessels, gadolinium diethyylenetrinine pentaacetic acid (gadolinium DTPA) renders blood vessels in a T1 MRI image white. (Gadolinium does not routinely cross the blood-brain barrier unless the barrier has broken down due to, say, tumors or infections.)

T2 pulses last four times as long as the T1 variety, which makes hydrogen nuclei, surrounded by water, a more suitable contrast. In T2 images, CSF appears white and areas that have an abnormally high water content (those affected by tumor, infection or stroke) look bright as well.

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In proton density images, CSF and the brain look the same, making it easier to see tissue changes next to ventricle structures.

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In addition to their clinical versatility, MRI scanners seem to cause no harm to biological tissue at exposures of 0.3-2.0 teslas of electromagnetic energy. And the technique has numerous applications; new ones are being discovered all the time. MRI can show atrophy changes of the brain common in Alzheimer's Dementia. It can detect tumors at earlier stages of development than many other forms of medical imaging. And it better reveals parts of the body that are not easily shown on the axial plane, including the cerebellum, where telltale changes take place in Parkinson's disease, Huntington's Chorea and Multiple Sclerosis.

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Answer posted on July 19, 1999

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ASK THE EXPERTS : MEDICINE

What happens to the body and brain of individuals with schizophrenia?

Sarah Nelson

Seattle, Washington

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Richard C. Deth, a professor of Pharmaceutical Science at Northeastern University, provides this answer:

Schizophrenia is a psychiatric disorder in which previously normal cognitive abilities and behaviors becomes disturbed. The most common age of onset is just after reaching adulthood, typically the late-teens to the mid-thirties. It is manifested either by so-called positive symptoms (delusions, hallucinations, unusual or disorganized behavior) or by negative symptoms, including a marked lack of activity, loss of interest and unresponsiveness.

Although the precise cause of schizophrenia remains unknown, an enormous amount of research has come up with a number of possibilities. Many early theories focused on behavioral or stress-induced events, but more recently, consensus holds that underlying biochemical abnormalities are more likely the cause. Lending great support to this idea is the fact that genetic predisposition may account for 50 percent of the risk of developing schizophrenia. Not surprisingly, these biochemical hypotheses center on dysfunction of the neurotransmitter systems in the brain, which provide for normal cognition and attention. The main theories include the Dopamine Hypothesis, the NMDA Receptor Hypothesis, the Single-carbon Hypothesis and the Membrane Hypothesis. And new research from our laboratory suggests that elements from each of these theories may play a role in schizophrenia.

The Dopamine Hypothesis: The notion that dopamine may be involved in schizophrenia derives from the therapeutic usefulness of drugs that block certain dopamine receptors in treating the disorder. Indeed, because dopamine blockers are so often effective, it has been proposed that an over activity of dopamine neurotransmission in cortical and limbic areas of the brain may cause schizophrenia. Drugs with selectivity for the D4 dopamine receptor (such as clozapine or olanzapine) can be particularly effective, and so this receptor subtype may play a critical role; in fact, elevated levels of D4 receptor binding have been found post-autopsy in the brains of persons who had schizophrenia. Dopamine is further implicated by the fact that a schizophrenia-like psychosis can be induced by abusing amphetamines, which act on dopamine pathways.

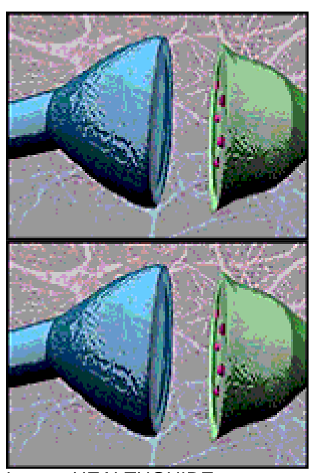

Image: HEALTHGUIDE

DOPAMINE has been linked to schizophrenia. In a brain with schizophrenia, far more neurotransmitters are released between neurons *(bottom),* than are in a normal brain *(top).*

The NMDA Receptor Hypothesis: NMDA receptors respond to the excitatory neurotransmitter glutamate, and are known to be important for normal memory and cognition. Because drugs affecting NMDA receptors (such as ketamine or phencyclidine (PCP)) can cause schizophrenia-like hallucinations and because neuroleptic drugs, including clozapine, can inhibit their occurrence, it has been suggested that NMDA receptor dysfunction may cause schizophrenia. Recent studies have shown therapeutic benefit from drugs acting on NMDA receptors, such as glycine and D-cycloserine.

The Single-Carbon Hypothesis: Researchers have often linked disturbances of the single-

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carbon folate pathway to schizophrenia. This metabolic pathway provides carbon groups for a variety of biochemical reactions in the brain, including the synthesis of purine and pyrimidine nucleotides and the methyl-donating amino acid methionine. A number of studies have shown that methionine metabolism is impaired in most schizophrenic persons, and other work has demonstrated enzyme deficits in the folate pathway in some schizophrenic persons. These observations are clear, but their relationship to neuronal transmission has remained elusive.

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Answer posted on July 05, 1999

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Doctor's Guide to the Internet on Schizophrenia
Schizophrenia.com, a non-profit information, support and education center
General Information on schizophrenia from the National Institute for Mental Health

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What causes strokes?

Morag Townsend
Ontario, Canada

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Augustine G. DiGiovanna, a biology professor at Salisbury State University and the author of *Human Aging: Biological Perspectives*, offers the following answer:

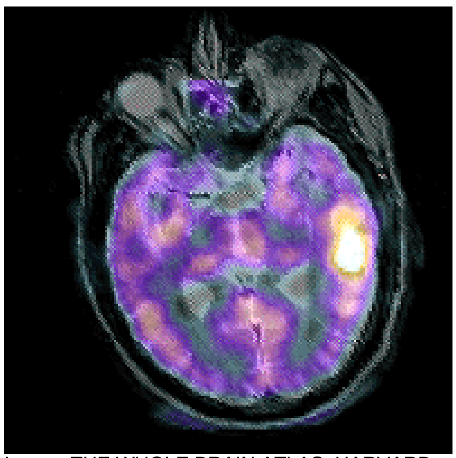

Image: THE WHOLE BRAIN ATLAS, HARVARD UNIVERSITY

BRAIN ATTACK. Strokes arise in two ways: when blood flow to the brain is reduced or when hemorrhaging occurs with in the brain itself. In both cases, neurons are starved of the oxygen they need to function. The ultimate outcome depends on where and how badly the brain is injured.

The constant activity of nerve cells in the brain requires an ongoing supply of chemical energy. Nerve cells, also called neurons, get this energy by breaking down glucose in a long series of reactions. Most of the energy emerges from the last few reactions, which require oxygen. The brain receives both glucose and oxygen through the blood, which is pumped up to the brain by the heart via arteries in the neck. (The pulse of blood in one of these arteries, the carotid, can be felt by pressing your fingers gently on the side of your neck). The arteries branch out at the brain, carrying blood over and through the organ.

If the supply of oxygen to the brain cells is inadequate, the neurons cannot break down glucose completely. As a result, they do not obtain enough energy for their activities; also, the partial breakdown of glucose yields harmful waste products. These conditions not only prevent nerve cells from functioning normally, but can also injure and kill them. Further damage may occur later when the blood flow is restored (reperfusion injury) and free radicals form. Either way, this damage causes brain malfunction, which becomes evident as the signs and symptoms of a stroke.

Strokes are also called cerebrovascular accidents (CVAs) because they result from abnormalities in the heart or blood vessels, which cause either a reduction in blood flow to areas in the brain or hemorrhaging within the brain itself. The first are called ischemic strokes and the second, hemorrhagic strokes. Strokes are classified based on the timing of the signs and symptoms, which vary widely depending on where and how badly the brain is damaged. An ischemic stroke having signs and symptoms that disappear within 24 hours is called a transient ischemic attack (TIA). TIAs often reoccur because blood flow to the same brain area is reduced and may eventually be followed by more serious strokes. In a reversible ischemic neurological deficit (RIND), the signs and symptoms subside more slowly. In a progressive stroke, signs and symptoms develop gradually and get worse over time. If the signs and symptoms develop quickly and show very little or no improvement over time, a completed stroke has occurred.

Most strokes result from atherosclerosis in arteries either within the brain or leading from the heart to the brain. Atherosclerosis leads to ischemic strokes by making arteries narrow, rough, stiff and weak. Narrowness reduces blood flow directly. Roughness reduces blood flow by causing the formation of blood clots (thrombi), which partially or completely block the vessel. Stiffness causes inadequate blood flow by preventing arteries from dilating when a region of the brain becomes more active and needs more oxygen or when blood pressure drops. Weakness in arteries can lead to reduced blood flow if the weak area bulges outward, forming

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an aneurysm. Though the region with the aneurysm is initially wider than normal, blood swirling in aneurysm can clot. As the clot enlarges, it can partially or completely block blood flow through the artery. Blood clots in arteries may break free of the vessel wall (embolize)--in which case flowing blood can push them into smaller arteries, where they block blood flow completely. Emboli formed by atherosclerotic plaque can also block arteries.

Answer posted on June 14, 1999

Related Links:
A review of cerebrovascular disease from the Mayo Clinic
Stroke information from the Doctor's Guide to the Internet

September 18, 2003

ASK THE EXPERTS : MEDICINE

What happens to the brain during a concussion?

Natasha Hocevar

Velenje, Slovenia

Richard Smayda, D.O., an osteopathic physician belonging to the American Osteopathic Association, practices integrative medicine, which merges alternative and conventional techniques. He gives the following answer:

A concussion is an immediate but reversible traumatic paralysis of the nervous function of the brain. It is usually caused by a blow to the head or by striking the head against a stationary object--blunt traumas that are differentiated as either acceleration or deceleration, respectively. In fact, a concussion is one of eight different types of traumatic brain injuries (TBI) that most commonly result from falls, motor vehicle accidents, sporting accidents and wrongful firearms discharges. (Direct impact is not the only manner of injury: it has been shown in primates that rapid acceleration of the head without impact can also result in concussion, although this injury is rare in humans.)

Image: HEAD INJURY SOCIETY OF NEW ZEALAND

BRAIN INJURY. On impact, the brain bumps into the interior of the skull where it is hit, as well as on the opposite side, resulting in damaging bruises at two sites in the brain, called the coup *(blue)* and the contrecoup *(red)*. Such injuries can cause a number of long-term effects.

Indeed, it is the rotational movements of the brain inside the calvaria (meaning all of the cranium except for the facial bones) and the shearing forces affecting the upper reticular formation that create torque, which leads to the typical loss of consciousness. These forces also cause the brain to move in a swirling fashion and contact the inner prominence of the skull, particularly the petrous and orbital ridges and the wings of the sphenoid. Such movement makes the brain bump into the interior of the skull at the point of impact, as well as on the opposite side of the skull, resulting in contusions (bruises) that damage two sites in the brain, called the coup and contrecoup injuries.

More so than the immediate impact (primary injury), however, a concussion involves a host of effects (secondary injuries) that emerge several hours or days after the trauma. It is critical for physicians to monitor these secondary tissue damages, as they are frequently the origin of significant long-term effects, including brain damage, cognitive deficits, psychosocial/ behavioral/emotional changes, bodily damage and biochemical changes at the cellular level.

Research has led to discoveries in the use of antioxidant therapy as a proactive measure to counteract the production of free radicals and thus stave off the potential for prolonged cellular damage. Two studies suggest that superoxide radical scavengers and superoxide dismutase may be useful in preventing the development of brain swelling, or edema.

From studies of the intracranial osmolality of cerebrospinal fluid, we have learned that a deliberate induction of hyperosmolality (increasing the intracranial concentration of cerebrospinal fluid) decreases the undesirable neurophysiological response that is characteristic of concussion injuries. Infusing mannitol serves to balance both the frequency and duration of the brain's electrical impulses, averting spikes that otherwise lead to seizure and reducing dangerous elevations in intracranial pressure that can lead to permanent brain damage.

Because so much is at stake when secondary injuries to concussions arise, it is critical that

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physicians initiate procedures to minimize this effect. In cardiovascular medicine, we remember the tenet "time is muscle," hence "time is white matter." Overall, it is agreed that emergent, aggressive preventive protocols are key for avoiding catastrophic permanent damage to the brain (with concomitant deficits in physical, psychological and behavioral functioning) that irreversibly affects an individual's quality of life.

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Answer posted on April 26, 1999

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Head Injury Hotline Telephone: (206) 621-8558
The Brain Injury Association Inc. Telephone: (800) 444-6443
The Virtual Hospital, from the University of Iowa Hospitals and Clinics

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ASK THE EXPERTS : MEDICINE

Is it true that creativity resides in the right hemisphere of the brain?

Michael Sheldrick
Houston, Tex.

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Ned Herrmann is an educator and consultant, who has spent two decades developing models of brain activity and its relationship to the creative process. Herrmann headed management education at General Electric and founded the Ned Herrmann Group in 1980. Here is his view.

In answering this question, I need to refer to both the left and right hemispheres, as well as the limbic system. The two hemispheres are frequently referred to as left brain/right brain.

The left brain/right brain concept of brain specialization was thoroughly researched and documented by the surgeon Joseph Bogen; Robert Ornstein, author of *The Psychology of Consciousness*; and Roger Sperry, the psychobiologist who conducted landmark "split brain" experiments, that earned him the Nobel Prize in medicine in 1981.

Bogen first suggested to Roger Sperry that he conduct experiments on his so-called "split brained" patients, those whose corpus callosi had been surgically separated to alleviate intractable epilepsy. These award-winning experiments demonstrated significant differences in the mental capabilities of the brain's two hemispheres. The left hemisphere was shown to be logical, analytic, quantitative, rational and verbal, whereas the right hemisphere was revealed to be conceptual, holistic, intuitive, imaginative and non-verbal. Thus a classic dichotomy was born.

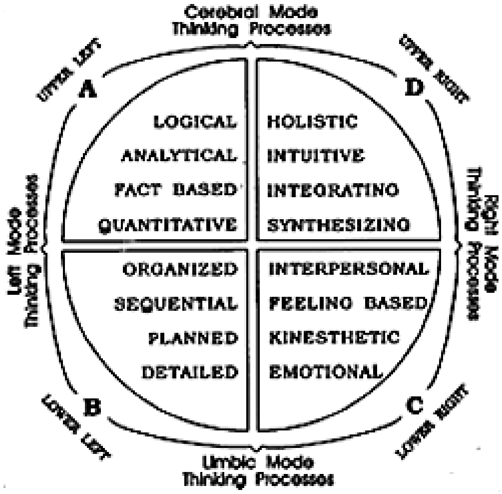
Many brain researchers and authors have documented this dichotomy extensively over the past 20 years. Ornstein was among the first, but many others followed. And, through their writing, they popularized the notion of left brain/right brain mental processing. But having personally researched both brain function and creativity for the same 20 years, I have concluded that creativity is a mental process utilizing all of the brain's specialized capabilities. It is, therefore, "whole brained."

The Whole Brain Model

The significant link to the right brain is pretty clear. The specialized characteristics of the right hemisphere make it the seat of curiosity, synergy, experimentation, metaphoric thinking, playfulness, solution finding, artistry, flexibility, synthesizing and in general, risk taking. In addition, it is likely to be opportunistic, future oriented, welcoming of change, and to function as the center of our visualization capability.

Every one of these specialized modes is capable of enhancing an individual's creative thinking. For example, an intuitive idea that pops into your mind and appears to solve a problem can be experimented with, visualized, integrated with other ideas and ultimately developed into a possible solution. That's the right hemisphere part.

Now, to do something about that possible solution requires different specialized mental processes, and these, by and large, are located in the left hemisphere. Diagnosing the proposed solution to determine whether it solves the real problem makes use of our rational processes of analysis and logic.



FOUR QUADRANTS define not only the left brain **(A, B)** and right brain **(C, D)** modes but also the cerebral **(A, D)** and limbic **(B, C)** modes.

The next creativity step might be how to factoring in sequence, timing or implementation procedures. Since the right hemisphere and the left hemisphere are massively interconnected (through the corpus callosum), it is not only possible, but also highly likely, that the creative person can iterate back and forth between these specialized modes to arrive at a practical solution to a real problem. If the right hemisphere were somehow disconnected from the left and confined to its own specialized thinking modes, it might be relegated to only "soft" fantasy solutions, pipe dreams or weird ideas that would be difficult, if not impossible, to fully implement in the real world. The left brain helps keep the right brain on track.

- **New!** Astronomy
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Answer posted on January 26, 1998

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ASK THE EXPERTS : MEDICINE

What is a headache?

Mark Mercieca

St. Andrews, Malta

Norman Harden is a neurologist in charge of the Center for Pain Studies at the Rehabilitation Institute of Chicago. He provides the following answer.

Narrowly defined, headache is pain in the head or face, and sometimes also includes pain in the upper neck. Pain sensitive structures in the head and face include the skin, bone and structures in the eyes, ears, nose and mouth. Also, the large blood vessels of the head are exquisitely sensitive and these are the principal organs causing pain in vascular headaches, such as migraines. The jaw hinge (called the temporomandibular joint) and the teeth can also generate headache. The brain itself is not pain sensitive and is not a source of head pain.

The most common type of headache is the tension or muscle contraction type, which is frequently caused by spasms in the neck muscles and the muscles of mastication (chewing). This type of headache is usually treated easily by over-the-counter medications. More intense headaches are caused by unknown mechanisms. Most theories of vascular headache involve the relationship between the nerves and the blood vessels, both of which can be sensitive.

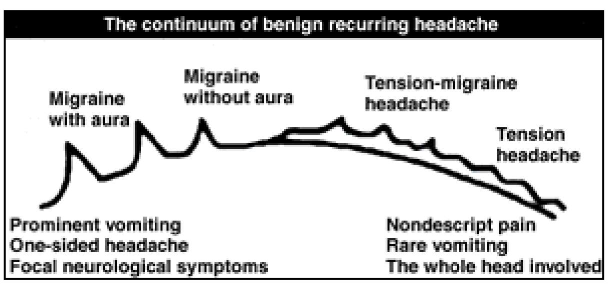

Image: American Council for Headache Education

In people who are prone to migraine, these headaches can be triggered by a multitude of causes, including diet, stress, lights, strong smells and other environmental conditions (either external or internal). Once the migraine process has started, it usually requires medication to stop the headache. There are many other specific, less common headache diagnoses, such as cluster headaches and neuralgia, or nerve damage headaches.

All of these headaches have specific treatments, both pharmacological and non-pharmacological (for instance, relaxation or biofeedback techniques). Additionally, there are new medications being developed on an almost monthly basis, all of which hold promise for treating these most painful of headaches. Anyone who suffers from headaches and who has given up on medical treatments should return to his or her family physician and inquire about the new prospects for substantial relief.

Answer posted on January 05, 1998

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ASK THE EXPERTS : MEDICINE

What is the function of the various brainwaves?

Larry Emond
Cleveland, Nova Scotia Canada

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Ned Herrmann is an educator who has developed models of brain activity and integrated them into teaching and management training. Before founding the Ned Herrmann Group in 1980, he headed management education at General Electric, where he developed many of his ideas. Here is his explanation.

It is well known that the brain is an electrochemical organ; researchers have speculated that a fully functioning brain can generate as much as 10 watts of electrical power. Other more conservative investigators calculate that if all 10 billion interconnected nerve cells discharged at one time that a single electrode placed on the human scalp would record something like five millionths to 50 millionths of a volt. If you had enough scalps hooked up you might be able to light a flashlight bulb.

Even though this electrical power is very limited, it does occur in very specific ways that are characteristic of the human brain. Electrical activity emanating from the brain is displayed in the form of brainwaves. There are four categories of these brainwaves, ranging from the most activity to the least activity. When the brain is aroused and actively engaged in mental activities, it generates beta waves. These beta waves are of relatively low amplitude, and are the fastest of the four different brainwaves. The frequency of beta waves ranges from 15 to 40 cycles a second. Beta waves are characteristics of a strongly engaged mind. A person in active conversation would be in beta. A debater would be in high beta. A person making a speech, or a teacher, or a talk show host would all be in beta when they are engaged in their work.

The Brainwaves

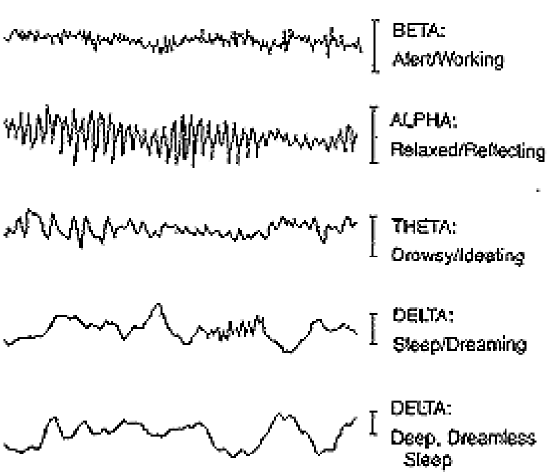

Image: Ned Herrmann, *The Creative Brain*

The next brainwave category in order of frequency is alpha. Where beta represented arousal, alpha represents non-arousal. Alpha brainwaves are slower, and higher in amplitude. Their frequency ranges from 9 to 14 cycles per second. A person who has completed a task and sits down to rest is often in an alpha state. A person who takes time out to reflect or meditate is usually in an alpha state. A person who takes a break from a conference and walks in the garden is often in an alpha state.

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The next state, theta brainwaves, are typically of even greater amplitude and slower frequency. This frequency range is normally between 5 and 8 cycles a second. A person who has taken time off from a task and begins to daydream is often in a theta brainwave state. A person who is driving on a freeway, and discovers that they can't recall the last five miles, is often in a theta state--induced by the process of freeway driving. The repetitious nature of that form of driving compared to a country road would differentiate a theta state and a beta state in order to perform the driving task safely.

Individuals who do a lot of freeway driving often get good ideas during those periods when they are in theta. Individuals who run outdoors often are in the state of mental relaxation that is slower than alpha and when in theta, they are prone to a flow of ideas. This can also occur in the shower or tub or even while shaving or brushing your hair. It is a state where tasks become so automatic that you can mentally disengage from them. The ideation that can take place during the theta state is often free flow and occurs without censorship or guilt. It is typically a very positive mental state.

The final brainwave state is delta. Here the brainwaves are of the greatest amplitude and slowest frequency. They typically center around a range of 1.5 to 4 cycles per second. They never go down to zero because that would mean that you were brain dead. But, deep dreamless sleep would take you down to the lowest frequency. Typically, 2 to 3 cycles a second.

When we go to bed and read for a few minutes before attempting sleep, we are likely to be in low beta. When we put the book down, turn off the lights and close our eyes, our brainwaves will descend from beta, to alpha, to theta and finally, when we fall asleep, to delta.

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Answer posted on December 22, 1997

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ASK THE EXPERTS : MATHEMATICS

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What is game theory and what are some of its applications?

Saul I. Gass, professor emeritus at the University of Maryland's Robert H. Smith School of Business, explains.

Game: A competitive activity involving skill, chance, or endurance on the part of two or more persons who play according to a set of rules, usually for their own amusement or for that of spectators (*The Random House Dictionary of the English Language,*1967).

Consider the following real-world competitive situations: missile defense, sales price wars for new cars, energy regulation, auditing tax payers, the TV show "Survivor," terrorism, NASCAR racing, labor- management negotiations, military conflicts, bidding at auction, arbitration, advertising, elections and voting, agricultural crop selection, conflict resolution, stock market, insurance, and telecommunications. What do they have in common? More >>

More Questions

On average, how many degrees apart is any one person in the world from another?

What is the origin of zero?

What is the origin of zero? How did we indicate nothingness before zero?

When is the beginning of the new millennium? Some say it is January 1, 2000 and others January 1, 2001? Who is correct?

Are mathematicians finally satisfied with Andrew Wiles's proof of Fermat's Last Theorem? Why has this theorem been so difficult to prove?

I've heard that the police are now using lasers in addition to radar to catch speeders on the highway. How does a laser measure the speed of a car?

Where does the "meter" come from? My professor said that the meter comes from the length of a pendulum that has a period of one second. This definition is close but not right on. My dictionary says the meter was originally defined as 1/10,000,000 of the distance from the equator to the pole, but I notice that is not exactly right either. When was the original meter defined? Is it just coincidence about the pendulum?

In the February issue of Scientific American, Phil and Phylis Morrison repeat the "purist" claim that the next millennium will start on January 1, 2001. This seems naive. When we count, we implicitly start with zero, not one. So why is the year 2000 not the first year of the third millennium?

Has chaos theory found any useful application in the social sciences?

Has there been any progress in developing fairer ways for people to vote in elections? I recall reading some time back about a system in which people would get one vote per candidate, not transferable between candidates; such a system was said to be fairer overall than one vote per voter.

What is pi, and how did it originate?

What is Godel's Theorem?

What is Russell's paradox?

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ASK THE EXPERTS : MATHEMATICS

On average, how many degrees apart is any one person in the world from another?

B. Sherwin

Provo, Utah

Duncan J. Watts, an associate professor of sociology at Columbia University and author of the forthcoming book *Six Degrees: The Science of a Connected Age* (Norton, 2003), is the principal investigator of the ongoing Small World Research Project. He provides the following explanation:

This is a question with rather a long history. As early as 1929, the Hungarian writer Frigyes Karinthy speculated that anyone in the world could be connected to anyone else through a chain consisting of no more than five intermediaries. Because the last person in the chain, who we call the target, does not count as an intermediary, five intermediaries is equivalent to six degrees of separation. The first scientific exploration of what was to become known as the "small-world problem" came almost three decades later in the work of Manfred Kochen (a mathematician) and Ithiel de Sola Pool (a political scientist), who proposed a mathematical explanation of the problem. Assuming that individuals choose 1,000 friends at random from a population as large as 100 million, Kochen and Pool showed that no more than two or three intermediaries (hence three or four degrees of separation) would be required to connect any two people. People, however, do not choose friends at random, which implies that the real answer should be higher. Kochen and Pool realized this, but were unable to solve the more difficult problem.

Stimulated by Pool and Kochen's work, the great social psychologist Stanley Milgram devised an ingenious experiment in the late 1960s to test the hypothesis. Milgram and his graduate student Jeffrey Travers gave 300 letters to subjects in Boston and Omaha, with instructions to deliver them to a single target person (a stockbroker from Sharon, Mass.) by mailing the letter to an acquaintance who the subject deemed closer to the target. The acquaintance then got the same set of instructions, thus setting up a chain of intermediaries. Milgram found that the average length of the chains that completed (64 of them) was about six--quite remarkable in light of Karinthy's prediction 40 years earlier. Since Milgram, the small-world problem has become a cultural phenomenon, especially after the playwright John Guare chose the catchy term "six degrees of separation" as the title of his 1990 play. But until recently, very little empirical work had been done aside from Milgram's initial experiment, and no one could explain why it worked.

Some recent theoretical work suggests that the answer may or may not be six, but it is certainly small--not 100, for example. A very large scale e-mail version of Milgram's experiment, currently being conducted at Columbia University (see link above), might settle the matter once and for all. But for now, it remains a mystery.

Answer posted on July 22, 2002

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Related Links:

Watts, D.J., Dodds, P.S., and Newman, M.E.J. Identity and search in social networks. *Science,* 296, 1302-1305 (2002).

Guare, J. *Six Degrees of Separation: A Play*. (Vintage Books, New York, 1990).

Watts, D.J. and Strogatz, S.H. Collective dynamics of 'small-world' networks. *Nature* 393, 440-442 (1998).

Pool, I. de Sola and Kochen, M. Contacts and Influence. *Social Networks* 1(1), 5-51 (1978).

Kleinberg, J. Navigation in a Small World. *Nature,* 406,845 (2000).

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ASK THE EXPERTS : MATHEMATICS

What is the origin of zero?

Rolf,

New York, NY

Robert Kaplan, author of *The Nothing That Is: A Natural History of Zero*, provides this answer:

The first evidence we have of zero is from the Sumerian culture in Mesopotamia, some 5,000 years ago. There a slanted double wedge was inserted between cuneiform symbols for numbers, written positionally, to indicate the absence of a number in a place (as we would write 102, the '0' indicating no digit in the tens column).

The symbol changed over time as positional notation, for which zero was crucial, made its way to the Babylonian empire and from there to India, via the Greeks (in whose own culture zero made a late and only occasional appearance; the Romans had no trace of it at all). Arab merchants brought the zero they found in India to the West, and after many adventures and much opposition, the symbol we use took hold and the concept flourished, as zero took on much more than a positional meaning and has played a crucial role in our mathematizing of the world.

The mathematical zero and the philosophical notion of nothingness are related but aren't the same. Nothingness plays a central role very early on in Indian thought (there called "sunya"), and we find speculation in virtually all cosmogonical myths about what must have preceded the world's creation. So in the Bible's book of Genesis (1:2): "And the earth was without form, and void."

But our inability to conceive of such a void is well caught in the book of Job, who cannot reply when God asks of him (Job 38:4): "Where wast thou when I laid the foundations of the earth? Declare, if thou hast understanding." Our own era's physical theories about the Big Bang cannot quite reach back to an ultimate beginning from nothing—although in mathematics we can generate all numbers from the empty set. Nothingness as the state out of which alone we can freely make our own natures lies at the heart of existentialism, which flourished in the mid-20th century.

Answer posted on October 04, 2001

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September 18, 2003

ASK THE EXPERTS : MATHEMATICS

What is the origin of zero? How did we indicate nothingness before zero?

Rolf,

New York, NY

Robert Kaplan has written The Nothing That Is: A Natural History of Zero and teaches at Harvard University. He provides this answer:

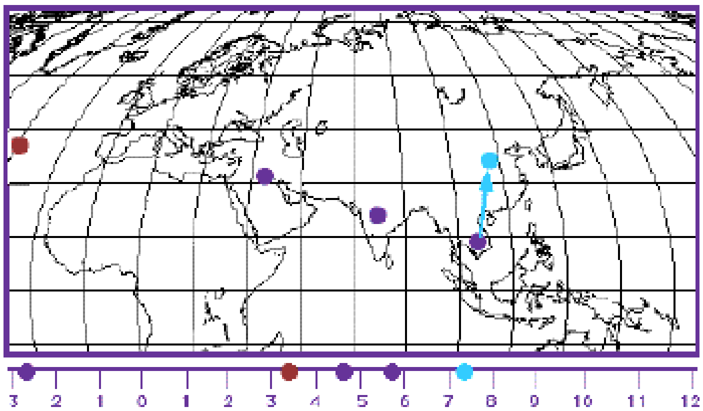

Image: KRISTEN MCQUILLIN

TIMELINE shows the development of zero throughout the world. The first recorded zero appeared in Mesopotamia around 3 B.C. The Mayans invented it independently around 4 A.D. It was then devised in India in the mid-fifth century. It spread to Cambodia near the end of the seventh century, and into China and the Islamic countries at the end of the eighth century. Zero reached western Europe in the 12th century.

The first evidence we have of zero is from the Sumerian culture in Mesopotamia, some 5,000 years ago. There a slanted double wedge was inserted between cuneiform symbols for numbers, written positionally, to indicate the absence of a number in a place (as we would write 102, the '0' indicating no digit in the tens column).

The symbol changed over time as positional notation, for which zero was crucial, made its way to the Babylonian empire and from there to India, via the Greeks (in whose own culture zero made a late and only occasional appearance; the Romans had no trace of it at all). Arab merchants brought the zero they found in India to the West, and after many adventures and much opposition, the symbol we use took hold and the concept flourished, as zero took on much more than a positional meaning and has played a crucial role in our mathematizing of the world.

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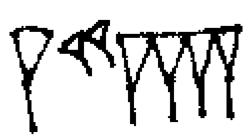
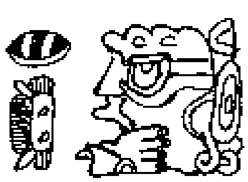
Writing Numbers



The Babylonians displayed zero with two angled wedges (middle).

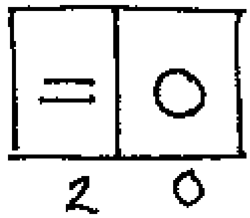


The Mayans used an eye-like character

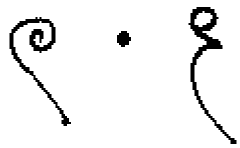
But our inability to conceive of such a void is well caught in the book of Job, who cannot reply when God asks of him (Job 38:4): "Where wast thou when I laid the foundations of the earth? Declare, if thou hast understanding." Our own era's physical theories about the Big Bang cannot quite reach back to an ultimate beginning from nothing--although in mathematics we can generate all numbers from the empty set. Nothingness as the state out of which alone we can freely make our own natures lies at the heart of Existentialism, which flourished in the mid-20th century.

Answer posted on February 28, 2000

(top left) to denote zero.



The Chinese started writing the open circle we now use for zero.



The Hindus depicted zero as a dot.

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ASK THE EXPERTS : MATHEMATICS

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In the February issue of Scientific American, Phil and Phylis Morrison repeat the "purist" claim that the next millennium will start on January 1, 2001. This seems naive. When we count, we implicitly start with zero, not one. So why is the year 2000 not the first year of the third millennium?

Wilton R. Abbott

Los Altos Hills, Calif.

For better or for worse, there is no year zero in our calendar. Rather, the chronology runs directly from 1 B.C. to 1 A.D.--and nothing in between. Therefore, the first century A.D. (or C. E., for Common Era) began on January 1 of the year 1, not of the year 0. The start of the second century would have been precisely 100 years after that, on January 1 of the year 101 A.D. By similar reasoning, the 21st century begins on January 1 of the year 2001, not of 2000. Thus goes the unassailable argument of the mathematical purists.

Mathematical logic is no match for human custom, however, which greatly complicates matters. Over the centuries, the calendar has been revised repeatedly. When Britain and its colonies switched from the Old Style Julian calendar to the more astronomically correct Gregorian calendar in 1752, by act of Parliament September 14 immediately followed September 2--a loss of 11 days. Strictly speaking, then, the 18th century was 11 days shorter than previous and subsequent centuries. Moreover, the packaging of years into decades, centuries, millenia or other units is more often a convention of convenience than of precision, and so may not be bound by strict rules of mathematical rigor.

So although the purists have reason on their side, the 21st century will probably begin when most people decide to celebrate it. Yet even that popular decision may not affect the date historians choose.

Answer posted on October 21, 1999

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ASK THE EXPERTS : MATHEMATICS

Has chaos theory found any useful application in the social sciences?

Allison Brown

Chicago, Ill.

Herbert A. Simon, professor of psychology at Carnegie Mellon University in Pittsburgh, responds:

"I have followed the development of chaos theory with some interest over the past decade or so, but without direct active involvement, so I may or may not be a reliable witness. The only serious efforts of which I am aware to apply chaos theory to social phenomena have been in economics--possibly because only in economics does one find the kinds of time-series data that would be required to test whether or not phenomena are chaotic. There have been a number of such tests for economic data--although even for economic phenomena, time series of the length and accuracy needed for testing are hard to come by, except in the case of some kinds of monetary series and series of stock prices. The verdict would seem to be that there is some indication of chaos in some of the series that have been examined. If that conclusion sounds vague, it is because the evidence looks vague to me.

"As a consequence, I would hesitate to say that chaos theory has had any major impact on the social sciences to date, although the idea that economic trends are difficult to forecast because they are chaotic remains an attractive one. There could be lots of other reasons for our inability to predict, however, all of which would have the same practical consequences.

"In psychology, where most of my own research resides, I have observed nothing of importance that relates to chaos, and I would be rather astonished if it plays any significant role in behavior extending over tens of milliseconds or longer--that is, the kind of behavior we observe and explain in most psychological experiments. But then, astonishment is what we are always seeking in good science, isn't it?"

James P. Crutchfield, research professor at the Sante Fe Institute and a research physicist at the University of California at Berkeley, adds a small plea:

"The phrase 'chaos theory' was invented, as far as I can tell, by the science press around the time of the publication of James Gleick's book *Chaos*. The proper descriptor, for better or for worse, is 'dynamical systems theory.' I hope I can disabuse people of using the popularized term, which I and many of my colleagues consider inappropriate.

Answer posted on October 21, 1999

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September 19, 2003

ASK THE EXPERTS : MATHEMATICS

What is game theory and what are some of its applications?

B. Royce

New York, NY

1 2 next »

Saul I. Gass, professor emeritus at the University of Maryland's Robert H. Smith School of Business, explains.

Game: A competitive activity involving skill, chance, or endurance on the part of two or more persons who play according to a set of rules, usually for their own amusement or for that of spectators (*The Random House Dictionary of the English Language,*1967).

Consider the following real-world competitive situations: missile defense, sales price wars for new cars, energy regulation, auditing tax payers, the TV show "Survivor," terrorism, NASCAR racing, labor- management negotiations, military conflicts, bidding at auction, arbitration, advertising, elections and voting, agricultural crop selection, conflict resolution, stock market, insurance, and telecommunications. What do they have in common?

A basic example helps to illustrate the point. After learning how to play the game tick-tack-toe, you probably discovered a strategy of play that enables you to achieve at least a draw and even win if your opponent makes a mistake and you notice it. Sticking to that strategy ensures that you will not lose.

This simple game illustrates the essential aspects of what is now called game theory. In it, a game is the set of rules that describe it. An instance of the game from beginning to end is known as a play of the game. And a pure strategy--such as the one you found for tick-tack-toe--is an overall plan specifying moves to be taken in all eventualities that can arise in a play of the game. A game is said to have perfect information if, throughout its play, all the rules, possible choices, and past history of play by any player are known to all participants. Games like tick-tack-toe, backgammon and chess are games with perfect information and such games are solved by pure strategies. But whereas you may be able to describe all such pure strategies for tick-tack-toe, it is not possible to do so for chess, hence the latter's age-old intrigue.

Games without perfect information, such as matching pennies, stone-paper-scissors or poker offer the players a challenge because there is no pure strategy that ensures a win. For matching pennies you have two pure strategies: play heads or tails. For stone-paper-scissors you have three pure strategies: play stone or paper or scissors. In both instances you cannot just continually play a pure strategy like heads or stone because your opponent will soon catch on and play the associated winning strategy. What to do? We soon learn to try to confound our opponent by randomizing our choice of strategy for each play (for heads-tails, just toss the coin in the air and see what happens for a 50-50 split). There are also other ways to control how we randomize. For example, for stone-paper-scissors we can toss a six-sided die and decide to select stone half the time (the numbers 1, 2 or 3 are tossed), select paper one third of the time (the numbers 4 or 5 are tossed) or select scissors one sixth of the time (the number 6 is tossed). Doing so would tend to hide your choice from your opponent. But, by mixing strategies in this manner, should you expect to win or lose in the long run? What is the optimal mix of strategies you should play? How much would you expect to win? This is where the modern mathematical theory of games comes into play.

Games such as heads-tails and stone-paper-scissors are called two-person zero-sum games. Zero-sum means that any money Player 1 wins (or loses) is exactly the same amount of money that Player 2 loses (or wins). That is, no money is created or lost by playing the game. Most parlor games are many-person zero-sum games (but if you are playing poker in a gambling hall, with the hall taking a certain percentage of the pot to cover its overhead, the game is not zero-sum). For two-person zero-sum games, the 20th century's most famous

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mathematician, John von Neumann, proved that all such games have optimal strategies for both players, with an associated expected value of the game. Here the optimal strategy, given that the game is being played many times, is a specialized random mix of the individual pure strategies. The value of the game, denoted by v, is the value that a player, say Player 1, is guaranteed to at least win if he sticks to the designated optimal mix of strategies no matter what mix of strategies Player 2 uses. Similarly, Player 2 is guaranteed not to lose more than v if he sticks to the designated optimal mix of strategies no matter what mix of strategies Player 1 uses. If v is a positive amount, then Player 1 can expect to win that amount, averaged out over many plays, and Player 2 can expect to lose that amount. The opposite is the case if v is a negative amount. Such a game is said to be fair if $v = 0$. That is, both players can expect to win 0 over a long run of plays. The mathematical description of a zero-sum two-person game is not difficult to construct, and determining the optimal strategies and the value of the game is computationally straightforward. We can show that heads-tails is a fair game and that both players have the same optimal mix of strategies that randomizes the selection of heads or tails 50 percent of the time for each. Stone-paper-scissors is also a fair game and both players have optimal strategies that employ each choice one third of the time. Not all zero-sum games are fair, although most two-person zero-sum parlor games are fair games. So why do we then play them? They are fun, we like the competition, and, since we usually play for a short period of time, the average winnings could be different than 0. Try your hand at the following game that has a $v = 1/5$.

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Answer posted on June 02, 2003

Related Links:

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www.gametheory.net
william-king.www.drexel.edu/top/eco/game/game.html

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ASK THE EXPERTS : MATHEMATICS

On average, how many degrees apart is any one person in the world from another?

B. Sherwin

Provo, Utah

Duncan J. Watts, an associate professor of sociology at Columbia University and author of the forthcoming book *Six Degrees: The Science of a Connected Age* (Norton, 2003), is the principal investigator of the ongoing Small World Research Project. He provides the following explanation:

This is a question with rather a long history. As early as 1929, the Hungarian writer Frigyes Karinthy speculated that anyone in the world could be connected to anyone else through a chain consisting of no more than five intermediaries. Because the last person in the chain, who we call the target, does not count as an intermediary, five intermediaries is equivalent to six degrees of separation. The first scientific exploration of what was to become known as the "small-world problem" came almost three decades later in the work of Manfred Kochen (a mathematician) and Ithiel de Sola Pool (a political scientist), who proposed a mathematical explanation of the problem. Assuming that individuals choose 1,000 friends at random from a population as large as 100 million, Kochen and Pool showed that no more than two or three intermediaries (hence three or four degrees of separation) would be required to connect any two people. People, however, do not choose friends at random, which implies that the real answer should be higher. Kochen and Pool realized this, but were unable to solve the more difficult problem.

Stimulated by Pool and Kochen’s work, the great social psychologist Stanley Milgram devised an ingenious experiment in the late 1960s to test the hypothesis. Milgram and his graduate student Jeffrey Travers gave 300 letters to subjects in Boston and Omaha, with instructions to deliver them to a single target person (a stockbroker from Sharon, Mass.) by mailing the letter to an acquaintance who the subject deemed closer to the target. The acquaintance then got the same set of instructions, thus setting up a chain of intermediaries. Milgram found that the average length of the chains that completed (64 of them) was about six--quite remarkable in light of Karinthy’s prediction 40 years earlier. Since Milgram, the small-world problem has become a cultural phenomenon, especially after the playwright John Guare chose the catchy term "six degrees of separation" as the title of his 1990 play. But until recently, very little empirical work had been done aside from Milgram’s initial experiment, and no one could explain why it worked.

Some recent theoretical work suggests that the answer may or may not be six, but it is certainly small--not 100, for example. A very large scale e-mail version of Milgram’s experiment, currently being conducted at Columbia University (see link above), might settle the matter once and for all. But for now, it remains a mystery.

Answer posted on July 22, 2002

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Related Links:

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ASK THE EXPERTS : MATHEMATICS

When is the beginning of the new millennium? Some say it is January 1, 2000 and others January 1, 2001? Who is correct?

Martina Paulovsky,
New York, NY

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The editors of *Scientific American* offer this explanation:

Years in the most popular calendar used today, the Gregorian calendar, are counted from the year A.D.1. There was no year 0. Before A.D.1 came the year B.C.1. Thus, the first century ran for 100 years from A.D.1 until the end of A.D. 100; the first millennium, from A.D.1 until the end of A.D. 1000; and so the current millennium will not end until December 31, A.D. 2000.

A 6th century scholar, Dionysius Exiguus (Dennis the Short), established the Gregorian calendar in A.D. 532 by fixing A.D. (Anno Domini)1 as the time of Jesus Christ's birth. In Dionysius' time, the notion of counting from 0 had not yet been introduced to Europe from the Middle East. Jesus Christ was more likely born in B.C. 6, but Dionysius' system has held firm throughout the years. There are, however, some 40 other calendar systems in use, all of which are in different years that change on different dates.

Calender System: Year
Gregorian.............2000
Byzantine.............7508
Chinese................4636
Indian...................1921
Islamic..................1420
Jewish.................5760

Officially, the new millennium will begin at zero hour, Greenwich Mean Time (GMT), also referred to as Coordinated Universal Time (UTC), on January 1, 2001, according to rules adopted at an international conference held in October 1884. But that same conference also decided that this reckoning "shall not interfere with the use of local or other standard time where desirable." In other words, everyone east of Greenwich will not postpone their parties past midnight local time, and everyone west won't celebrate early.

The year 2000 is special--even though it isn't the start of the 21st century--because it is a leap year. Julius Caesar devised the leap year to correct for the fact that the earth circles the sun in 352.24219 days. Because this is not a whole number, the months of the year would slowly fall out of sync with the seasons. A fairly precise correction to the Gregorian calendar debuted in 1582, and stated that a century year will only be a leap year if it is evenly divisible by 400--which is true for Y2K.

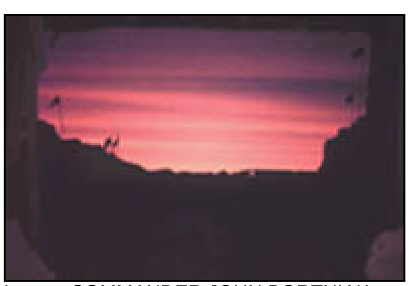

Image: COMMANDER JOHN BORTNIAK, *NOAA Corps*

DAWN OF A NEW MILLENIUM on January 1, 2001 will shine first in Antarctica and resemble the breaking sunrise above.

Frank Morgan, the Meenan Third Century Professor of Mathematics at Williams College, gives the following answer, adapted from his upcoming *Math Chat Book,* which is based on his *Math Chat* TV show and column, both available at the Mathematical Association of America's Web site:

The inexorable mathematical logic is that the official calendar millennium does not start until the year 2001. The first 2000 years end with the year 2000, and the next thousand start with 2001, the first year of the third millennium. Imagine a vast army of soldiers, with 1,000 men in each row. In the first row are soldiers 1 to 1,000, in the second, 1,001 to 2,000, and in the third, 2,001 to 3,000. The third row starts with soldier 2,001. Or suppose you work 1,000 hours a year. The first year, you work hours 1 to 1,000, the second year hours 1,001 to 2,000, and the third year begins with your 2,001st hour of work. So we should definitely celebrate the official calendar millennium on January 1, 2001.

But there is another millennium to celebrate: the millennium of the 2000s, the years that begin with a 2. This change will affect every check we write, every letter we date. It is exciting to see all the digits roll over for the first time since the year advanced from 999 to 1000, when Ethelred II was king of England; as exciting as seeing the odometer in my Ferrari roll over from 99,999 to 100,000 or seeing the whole Senate roll over to 100 new Senators (which probably never will happen, but then again, I don't really have a Ferrari either). Of course, this change in date is what causes the Y2K problems with computers, which will interpret '00 as 1900 instead of 2000. So maybe it's safer to wait until the official 2001 to celebrate.

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Answer posted on December 20, 1999

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New Millennium from the Royal Observatory Greenwich
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ASK THE EXPERTS : ASTRONOMY

How do planets acquire rings?

Astrophysicist George F. Spagna, Jr., of Randolph-Macon College provides this explanation:

The bright rings of Saturn have puzzled scientists ever since Galileo first observed them in about 1610. He initially thought of Saturn as a triple planet because he could discern only two irregular blobs of light, one on either side of the planet itself. Then in 1655 Christian Huygens proposed that these blobs were actually a flattened system of rings circling the planet above its equator.

We now know that rings circle all four of the gas giant planets in our solar system—Jupiter, Saturn, Uranus and Neptune—though only Saturn's are obvious when viewed from Earth. Contrary to their appearance, they are not solid rings or disks at all. Rather they are composed of myriad bits and pieces of ice, rock and dust. In the case of Saturn's brightly visible rings, they consist of more ice, which reflects sunlight effectively. The rings of the other planets contain mostly dust, which is dark and doesn't reflect much light. Additionally, whereas Saturn's rings are wide, the other planets sport thin rings. More >>

More Questions

Why and how do planets rotate?

How long do stars usually live?

What exactly is the North Star?

Why do stars twinkle?

If there is no gravity in space, why do "shooting stars" fall?

Why is the Oort cloud not a disc?

What is a blue moon?

Why are planets round?

Can you explain how jet propulsion engines work?

How is a star born?

Images of astronomical nebulae look startlingly like clouds on the sky on the earth, even though they are vastly different in size and composition. Why is this? Are the dynamic processes that shape these cosmic structures the same as those at work in our atmosphere?

According to the big bang theory, all the matter in the universe erupted from a singularity. Why didn't all this matter--cheek by jowl as it was--immediately collapse into a black hole?

How do astronomers measure the distances to galaxies that are millions or even billions of light-years away? I understand that trigonometric parallax can be used to measure distances out to only a couple of hundred light-years away. How do we get from there to the edge of the universe?

How do we know that distant galaxies are composed of matter rather than anti-matter? If equal quantities of each were produced in the big bang, might not some parts of the universe contain primarily matter and other parts primarily anti-matter?

Is the violent behavior of quasars caused by black holes in galaxies? If so, does the discovery

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of black holes in the centers of many normal galaxies mean that all galaxies were once quasars?

According to the big bang, space itself is expanding. I don't understand: If space is expanding, into what is it expanding?

Astronomers have now discovered about 10 planets orbiting other stars. When and how will these planets receive names? Who gets to name them?

How do scientists determine the ages of stars? Is the technique really accurate enough to use it to verify the age of the universe?

Why are scientists so sure that the Martian meteorite that has been in the news recently really came from Mars? Couldn't it have been dislodged from Earth by an asteroid impact and then returned millions of years later? Couldn't the early Earth (or some distant asteroid) once have been chemically similar to Mars?

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September 03, 2003

ASK THE EXPERTS : ASTRONOMY

Why and how do planets rotate?

A. P. Erson

Leesburg, Fla.

George Spagna, chair of the physics department at Randolph-Macon College, explains.

Stars and planets form in the collapse of huge clouds of interstellar gas and dust. The material in these clouds is in constant motion, and the clouds themselves are in motion, orbiting in the aggregate gravity of the galaxy. As a result of this movement, the cloud will most likely have some slight rotation as seen from a point near its center. This rotation can be described as angular momentum, a conserved measure of its motion that cannot change. Conservation of angular momentum explains why an ice skater spins more rapidly as she pulls her arms in. As her arms come closer to her axis of rotation, her speed increases and her angular momentum remains the same. Similarly, her rotation slows when she extends her arms at the conclusion of the spin.

As an interstellar cloud collapses, it fragments into smaller pieces, each collapsing independently and each carrying part of the original angular momentum. The rotating clouds flatten into protostellar disks, out of which individual stars and their planets form. By a mechanism not fully understood, but believed to be associated with the strong magnetic fields associated with a young star, most of the angular momentum is transferred into the remnant accretion disk. Planets form from material in this disk, through accretion of smaller particles.

In our solar system, the giant gas planets (Jupiter, Saturn, Uranus, and Neptune) spin more rapidly on their axes than the inner planets do and possess most of the system's angular momentum. The sun itself rotates slowly, only once a month. The planets all revolve around the sun in the same direction and in virtually the same plane. In addition, they all rotate in the same general direction, with the exceptions of Venus and Uranus. These differences are believed to stem from collisions that occurred late in the planets' formation. (A similar collision is believed to have led to the formation of our moon.)

Answer posted on April 14, 2003

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September 03, 2003

ASK THE EXPERTS : ASTRONOMY

How long do stars usually live?

A. Tate
Willard, Mo.

John Graham, an astronomer at the Carnegie Institution of Washington, explains.

The length of a star's life depends on how fast it uses up its nuclear fuel. Our sun, in many ways an average sort of star, has been around for nearly five billion years and has enough fuel to keep going for another five billion years. Almost all stars shine as a result of the nuclear fusion of hydrogen into helium. This takes place within their hot, dense cores where temperatures are as high as 20 million degrees. The rate of energy generation for a star is very sensitive to both temperature and the gravitational compression from its outer layers. These parameters are higher for heavier stars, and the rate of energy generation--and in turn the observed luminosity--goes roughly as the cube of the stellar mass. Heavier stars thus burn their fuel much faster than less massive ones do and are disproportionately brighter. Some will exhaust their available hydrogen within a few million years. On the other hand, the least massive stars that we know are so parsimonious in their fuel consumption that they can live to ages older than that of the universe itself--about 15 billion years. But because they have such low energy output, they are very faint.

When we look up at the stars at night, almost all of the ones we can see are intrinsically more massive and brighter than our sun. Most longer-lasting stars that are fainter than the sun are just too dim to view without telescopic aid. At the end of a star's life, when the supply of available hydrogen is nearly exhausted, it swells up and brightens. Many stars that are visible to the naked eye are in this stage of their life cycles because this bias brings them preferentially to our attention. They are, on average, a few hundred million years old and slowly coming to the end of their lives. A massive star such as the red Betelgeuse in Orion, in contrast, approaches its demise much more quickly. It has been spending its fuel so extravagantly that it cannot be older than about 10 million years. Within a million years, it is expected to go into complete collapse before probably exploding as a supernova.

Stars are still being born at the present time from dense clouds of dust and gas, but they remain deeply embedded in their placental material and cannot be seen in visible light. The enveloping dust is transparent to infrared radiation, however, so scientists using modern detecting devices can easily locate and study them. In so doing, we hope to learn how planetary systems like our own come together.

Answer posted on February 24, 2003

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September 03, 2003

ASK THE EXPERTS : ASTRONOMY

What exactly is the North Star?

J. Elmore

Mt. Juliet, Tenn.

Rich Schuler, an adjunct instructor and outreach coordinator in the physics and astronomy department at the University of Missouri-St. Louis, explains.

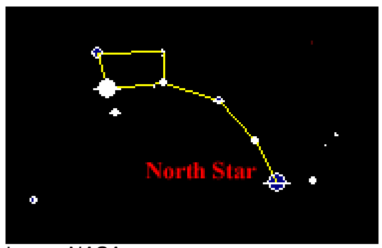

Image:*NASA*

A STAR MAP shows the relative position of Polaris in Ursa Minor.

The North Star, or Polaris, is the brightest star in the constellation Ursa Minor, the little bear (also known as the Little Dipper). As viewed by observers in the Northern Hemisphere, Polaris occupies a special place. The point in the night sky where the projection of the earth's axis lies is known as the North Celestial Pole (NCP). As the earth rotates on its axis (once every 24 hours), the stars in the northern sky appear to revolve around the NCP. Polaris lies roughly one half degree from the NCP, so this particular star appears to remain stationary hour after hour and night after night.

Because the earth is spherical, the position of Polaris relative to the horizon depends on the location of the observer. Consequently, the angle between the northern horizon and Polaris is equal to the observer's latitude. For example, when viewed from the equator (0 degrees latitude), Polaris lies on the northern horizon. As an observer moves northward--say, to Houston, Tex. (30 degrees latitude)-- Polaris is located 30 degrees above the northern horizon. This trend continues until the traveler reaches the geographic (not magnetic) North Pole. At this point (90 degrees latitude), Polaris is 90 degrees above the northern horizon and appears directly overhead.

Elmore further asked, "Did travelers in the past actually depend on the North Star to guide them?"

A traveler on land or sea need only measure the angle between the northern horizon and Polaris to determine his or her latitude. Thus, Polaris is a handy tool for finding the northern extent of one's position, or latitude, and was therefore heavily utilized by travelers in the past—especially sailors.

Unfortunately, latitude alone is insufficient to pinpoint a location on the surface of the earth. Lines of constant latitude circle the earth parallel to the equator. With only latitude in hand, an individual knows just that he or she is on a particular "latitude circle." Without an accompanying longitude coordinate, an observer could be located at any position on the circumference of the planet consistent with the measured latitude. Although many cultures

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succeeded in making long ocean voyages using only the stars, weather and currents, the "longitude problem" plagued sailors for millennia and remained unsolved until the invention of a clock that could keep accurate time while a ship rolled, pitched and yawed on the sea (circa 1740).

There is currently no star in the Southern Hemisphere that coincides with the South Celestial Pole. Furthermore, Polaris is not an absolute guide to measuring latitude on the earth for Northern Hemisphere observers. In addition to the daily 24-hour rotation cycle, the axis of the earth precesses in a conical motion. Thus, the projection of the earth's axis traces a circle in the northern (and southern) sky with a period of 26,000 years. The location of the North (and South) Celestial Pole is defined by projecting the axis of the earth onto the celestial sphere; consequently, as the axis changes position, so, too, does the "North Star." As a result, 5,000 years ago the earth's axis pointed toward Draco, and the North Star was Thuban. Similarly, in 12,000 years the star Vega (in the constellation Lyra) will be the North Star.

Answer originally posted February 18, 2002.

Answer posted on December 23, 2002

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ASK THE EXPERTS : ASTRONOMY

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Why do stars twinkle?

Stacie

Solon, Ohio

John A. Graham, an astronomer with the Carnegie Institution of Washington, explains.

Have you ever noticed how a coin at the bottom of a swimming pool seems to wobble from side to side? This phenomenon occurs because the water in the pool bends the path of light from the coin. Similarly, stars twinkle because their light has to pass through several miles of Earth's atmosphere before it reaches the eye of an observer. It is as if we are looking up at the universe from the bottom of a swimming pool. Our atmosphere is very turbulent, with streams and eddies forming, churning around and dispersing all the time. These disturbances act like lenses and prisms that shift the incoming light from a star from side to side by minute amounts several times a second. For large objects like the moon, these deviations average out. (Through a telescope with high magnification, however, we see shimmering images.) Stars, in contrast, are so far away that they effectively act as point sources, and the light we see flickers in intensity as the incoming beams bend rapidly from side to side. Planets like Mars, Venus and Jupiter, which appear to us as bright stars, are much closer to Earth and look like measurable discs through a telescope. Again, the twinkling from adjacent areas of the disc averages out, and we see little variation in the total light emanating from the planet.

In outer space, where there is no atmosphere, stars do not twinkle. This is why the Hubble Space Telescope can produce the brilliant and crisp images of the universe that we have come to know. At our Earthbound observatories, we are learning how to compensate for the twinkling effect by adapting the optics of our large telescopes as fast as it occurs. As a result, we should soon be able to produce much sharper images from here on the ground.

Answer posted on August 05, 2002

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ASK THE EXPERTS : ASTRONOMY

If there is no gravity in space, why do "shooting stars" fall?

K. Thomas

Berkeley, Calif.

Rich Schuler, an adjunct instructor and outreach coordinator in the physics and astronomy department at the University of Missouri-St. Louis, provides the following explanation.

Gravity can be thought of as a side effect of matter, because any object that has mass generates a gravitational field. If two or more objects are present, then a gravitational force arises between the bodies. This force is always attractive, so objects are always drawn together by gravity.

Isaac Newton was the first scientist to quantify the gravitational force, in 1684. Newton discovered that the gravitational force between every particle of the universe is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. Therefore:

$$F_g = \frac{G m_1 m_2}{r^2}$$

where Fg is the force due to gravity, *G* is Newton's gravitational constant, *m1* is the mass of one object, *m2* is the mass of the second object, and *r* is the distance between the objects.

As a result, although gravitational force decreases rapidly with distance, the magnitude of the force does not reduce to zero until the separation between two bodies is infinitely large. The universe is immense; however, it is far from infinite in extent. Thus, no particle in the universe is free from gravitational forces. This includes the earth as it revolves around the sun, as well as meteors (or falling stars) and satellites.

Unfortunately, the term "zero gravity" was coined to describe the forces experienced by astronauts in orbit. But an astronaut working in the shuttle bay in an orbit of 300 kilometers (186 miles) is still subjected to the gravitational force of the earth. Because the magnitude of the force is inversely proportional to the square of the distance separating the astronaut and the planet's center, the gravitational force between the astronaut and the earth is roughly 91 percent of the value he or she would experience on the earth's surface. As a result, while in orbit astronauts experience weightlessness not because there is no gravity in space but because an orbiting body is in a constant state of free fall. The astronaut is merely falling around the earth at the same rate as the shuttle is. If the velocity of the space shuttle were to suddenly become zero, it would fall toward the earth and burn up in the atmosphere.

A meteor is a small piece of debris (or meteoroid) that burns up as it enters the earth's atmosphere and is seen by observers as a momentary streak of light. Commonly known as "shooting," or "falling," stars, these objects vary in size from mere dust specks to small bits of rock and metal with masses typically less than one gram (weight of 0.04 oz.). A meteoroid enters the atmosphere at very high speeds (between 10 and 70 kilometers a second, or 20,000 to 150,000 miles an hour) that cause the surface of the object to heat up via friction. The surface of the meteoroid vaporizes and leaves high-temperature atoms, as well as heated

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molecules, in its wake. The superheated meteor atoms and molecules then glow in a process that is similar to a fluorescent bulb. Thus, when you see a falling star, a piece of debris the size of a grain of sand has been converted into heat, a visible streak of light and atom-size dust particles.

Answer posted on June 24, 2002

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ASK THE EXPERTS : ASTRONOMY

Why is the Oort cloud not a disc?

T. Creighton

London, England

Paul Weissman, a senior research scientist at NASA's Jet Propulsion Laboratory, offers the following answer.

The Oort cloud is a huge spherical cloud of some 10^{12} comets surrounding the solar system and extending halfway to the nearest stars. We believe that the Oort cloud comets originated as icy planetesimals between the orbits of Jupiter, Saturn, Uranus and Neptune, and were dynamically ejected to their current distant orbits by gravitational interactions with those giant planets.

The ejection process scatters the comets not only to large orbits but also to moderately large inclinations, on the order of 20 or 30 degrees. Once in the Oort cloud, gravitational perturbations from random passing stars, from encounters with giant molecular clouds in the galaxy, and from the galactic tide continue to modify the cometary orbits. Because these perturbations occur when the comets are close to aphelion (the farthest point from the sun) in their very eccentric orbits, they are most effective at changing the angular momentum of the orbit. The angular momentum figures most importantly in determining the perihelion distance of the comet (the point at which it is nearest to the sun) and its orbital inclination. As a result, the perihelia of the comets tend to diffuse away from the planetary region and the inclinations of the orbits continue to grow.

As an example, a comet with a perihelion distance of about 10 astronomical units (AU), near the orbit of Saturn, and an aphelion distance of 50,000 AU, typical for the Oort cloud, moves at a velocity of only 2.7 meters per second at aphelion. A one-solar-mass star passing at a distance of 1 parsec (206,265 AU) at a velocity of 30 kilometers per second will perturb the velocity of the comet by about 0.29 meter per second. That is enough to raise the perihelion distance to 12.3 AU or to increase the orbital inclination by about six degrees. Because a comet will receive on the order of 40,000 such perturbations over its lifetime, it is easy to see how the inclinations and perihelion distances of the orbits can be completely randomized. The result is a spherical Oort cloud.

Creighton further questioned whether the mass contained within the Oort cloud could cause the orbital plane of the solar system to tilt.

Will the mass of the Oort cloud affect the plane of the planetary system? Not very much. To begin with, the total mass of comets in the Oort cloud is estimated to be between about five and 50 Earth masses, with a best guess value near 15 Earth masses. This can be compared with the total mass of the planets of 446.7 Earth masses. So changes in the Oort cloud orbits would have only a small effect on the entire planetary system. Moreover, because the perturbations of the Oort cloud are random, the orbital inclinations can be changed positively

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or negatively, and the net effect of the external perturbations is likely to be statistically close to zero. So again, the effect on the rest of the planetary system is going to be very small.

Answer posted on March 04, 2002

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September 03, 2003

ASK THE EXPERTS : ASTRONOMY

What is a blue moon?

B. Purvis

Carlisle, Pa.

George Spagna, chair of the physics department at Randolph-Macon College, provides the following explanation.

Image: *NASA*

A FULL MOON, as photographed from Apollo 11, appears above. The second full moon in a month is commonly called a blue moon.

A "blue moon" once meant something impossible or at least highly unlikely, much like the expression "when donkeys fly!" This was apparently the usage as early as the 16th century.

Then in 1883, the explosion of Krakatau in Indonesia threw enough dust into the atmosphere to turn worldwide sunsets green and the moon blue. Forest fires, prolonged drought and volcanic eruptions can still do this. So a blue moon became synonymous with something rare—hence the phrase "once in a blue moon."

The connection of a blue moon with the calendar apparently comes from the *Maine Farmers' Almanac* published in 1937. The *almanac* relies on the tropical year, which runs from winter solstice to winter solstice. In it, the seasons are not identical in length because the earth's orbit is elliptical rather than circular. Further, the synodic month is approximately 29.5 days, which doesn't fit evenly into a 365.24-day tropical year, nor into seasons only approximately three months in length.

Most tropical years have 12 full moons, but occasionally there will be 13, so one of the seasons will get four. They called the occasional third full moon in that season in which there happened to be four a blue moon. (The full moons closest to the equinoxes and solstices already have traditional names.) J. Hugh Pruett, writing in *Sky and Telescope* in 1946, misinterpreted their version to mean the second full moon in a given month. That version was repeated in a broadcast on National Public Radio's *Star Date* in 1980, and the definition has stuck!

Although it is true that the phrase comes from a folk tale, the current folk tale isn't very old. So when someone talks about a blue moon today, they are referring to the second full moon in a month.

Answer posted on December 31, 2001

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Why are planets round?

K. Schumacher,

via e-mail

Derek Sears, professor of cosmochemistry at the University of Arkansas and editor of the journal *Meteoritics and Planetary Science,* provides the following explanation:

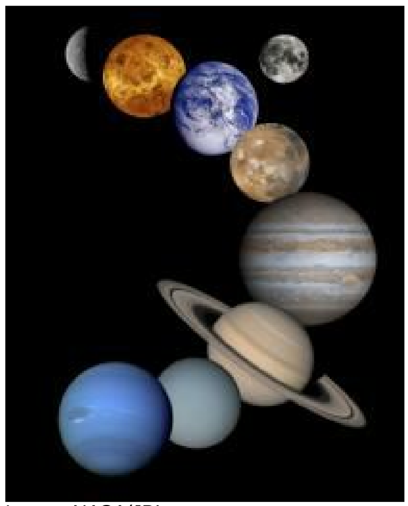
Image: *NASA/JPL*

Planets are round because their gravitational field acts as though it originates from the center of the body and pulls everything toward it. With its large body and internal heating from radioactive elements, a planet behaves like a fluid, and over long periods of time succumbs to the gravitational pull from its center of gravity. The only way to get all the mass as close to planet's center of gravity as possible is to form a sphere. The technical name for this process is "isostatic adjustment."

With much smaller bodies, such as the 20-kilometer asteroids we have seen in recent spacecraft images, the gravitational pull is too weak to overcome the asteroid's mechanical strength. As a result, these bodies do not form spheres. Rather they maintain irregular, fragmentary shapes.

Answer posted on July 30, 2001

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ASK THE EXPERTS : ASTRONOMY

Can you explain how jet propulsion engines work?

Gareth Young,
Buckley, Flintshire, England

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Awatef Hamed, Professor of Aerospace Engineering and Engineering Mechanics at the University of Cincinnati, provides this explanation:


Awatef Hamed

Jet propulsion revolutionized the science of flight by dramatically increasing possible speeds and altitudes, hence enabling space exploration. The term jet propulsion refers to the action produced by a reactor to the ejection of matter. For example, when the matter in a typical rocket (like gunpowder in fireworks) is ignited, the resulting chemical reaction produces heat and gases, which escape from the rocket and cause it to move forward. The oxygen necessary for combustion is carried (in tanks or in a combined form) in the rocket itself so that the rocket thrust is independent of the atmosphere. Other jet propulsion devices depend on the air inducted into the engine to supply the necessary oxygen. After heat is released by the combustion, the hot gases are accelerated through the engine so that the exit velocity is greater than the airstream velocity at the entrance.

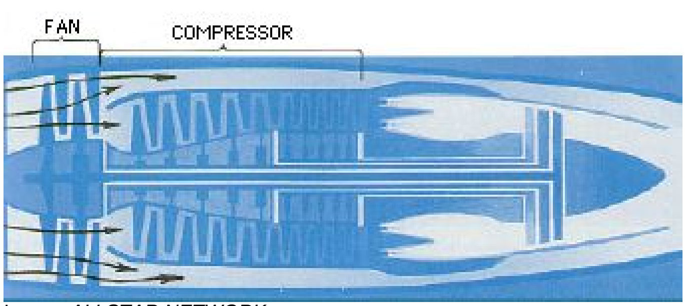

Image: *ALLSTAR NETWORK*
TURBOFAN ENGINES eject rearward a large mass of material at a low velocity to produce forward thrust.

In both self-contained rocket motors and air-breathing jet propulsion power units, the thrust that can be generated is proportional to the mass of material ejected from the unit in a given time, as well as the increase in the mass velocity with respect to the unit. Therefore, the same forward-thrust force can be produced in two ways: by ejecting rearward either a large mass of material at a low velocity during a given time period (as in turbofan engines) or by ejecting a

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smaller mass of material at higher velocity (as in turbojet and ramjet engines). The two sources of mass are the propellant, or fuel, and the oxidizer, or air.

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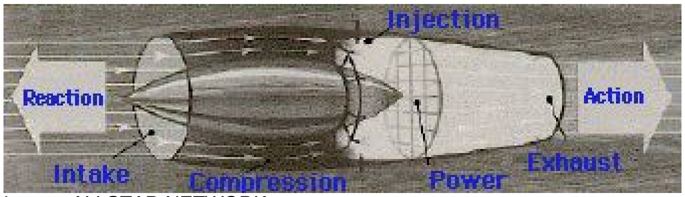

Image: *ALLSTAR NETWORK*

RAMJET ENGINES produce thrust by ejecting a smaller mass of material at higher velocity than do turbofan engines.

Fuels contain a large quantity of potential energy, which is rapidly released during combustion. A portion of this heat energy is converted into useful work, moving the vehicle through the atmosphere or into space. Another portion, however, in the form of the jet's kinetic energy, is lost and dissipates into the atmosphere. The very fuel-efficient turbofan engines used in modern commercial aircraft engines attempt to minimize the latter portion. To do so, they impart a moderate increase in the mass velocity to the combustion products for the large mass of air drawn through the engine in a given time. But turbojet and ramjet engines, which meet more demanding supersonic flight requirements, are less fuel-efficient.

Various types of jet engines have been developed to deliver the required thrust and engine performance for a wide range of flight speeds and altitudes. Air-breathing turbojet, turbofan and ramjet engines operate according to similar principles in the sense that they raise the inducted air pressure before combustion and expand the high-energy gases before they leave, in a nozzle or exhaust system. In turbojet engines, the inducted air goes through a compressor to increase its pressure before entering the combustor, then through a turbine before accelerating in the exhaust nozzle. The ramjet engine, though, has no moving parts; it produces a ram pressure rise from decelerating the high-speed inducted air in the inlet diffuser. The ramjet engine can only operate at high supersonic velocities and therefore requires another launching device, such as a rocket or turbojet engine, to accelerate it to the required speed.

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ASK THE EXPERTS : ASTRONOMY

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How is a star born?

Martha Birch,

Manalapan, N.J.

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Richard Brill, an associate professor at Honolulu Community College, offers the following answer:


Richard Brill

A star is born when atoms of light elements are squeezed under enough pressure for their nuclei to undergo fusion. All stars are the result of a balance of forces: the force of gravity compresses atoms in interstellar gas until the fusion reactions begin. And once the fusion reactions begin, they exert an outward pressure. As long as the inward force of gravity and the outward force generated by the fusion reactions are equal, the star remains stable.

Clouds of gas are common in our galaxy and in other galaxies like ours. These clouds are called nebulae. A typical nebula is many light-years across and contains enough mass to make several thousand stars the size of our sun. The majority of the gas in nebulae consists of molecules of hydrogen and helium--but most nebulae also contain atoms of other elements, as well as some surprisingly complex organic molecules. These heavier atoms are remnants of older stars, which have exploded in an event we call a supernova. The source of the organic molecules is still a mystery.

Irregularities in the density of the gas causes a net gravitational force that pulls the gas molecules closer together. Some astronomers think that a gravitational or magnetic disturbance causes the nebula to collapse. As the gases collect, they lose potential energy, which results in an increase in temperature.

As the collapse continues, the temperature increases. The collapsing cloud separates into many smaller clouds, each of which may eventually become a star. The core of the cloud collapses faster than the outer parts, and the cloud begins to rotate faster and faster to conserve angular momentum. When the core reaches a temperature of about 2,000 degrees Kelvin, the molecules of hydrogen gas break apart into hydrogen atoms. Eventually the core reaches a temperature of 10,000 degrees Kelvin, and it begins to look like a star when fusion reactions begin. When it has collapsed to about 30 times the size of our sun, it becomes a protostar.

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When the pressure and temperature in the core become great enough to sustain nuclear fusion, the outward pressure acts against the gravitational force. At this stage the core is about the size of our sun. The remaining dust envelope surrounding the star heats up and glows brightly in the infrared part of the spectrum. At this point the visible light from the new star cannot penetrate the envelope. Eventually, radiation pressure from the star blows away the envelope and the new star begins its evolution. The properties and lifetime of the new star depend on the amount of gas that remains trapped. A star like our sun has a lifetime of about 10 billion years and is just middle-aged, with another five billion years or so left.

Margaret M. Hanson, an assistant physics professor at the University of Cincinnati, gives this response:

Stars form from the gravitational collapse of large clouds of interstellar material. In fact, the space between stars is not empty; it is nearly empty, but not entirely. Interstellar matter, that found lying between the stars, is made from gas and dust. Granted, only about 10 percent of the mass in our Milky Way galaxy is made up of interstellar matter. But this material, as tenuous as it is, exerts a gravitational force, and as a result, it will begin to pull itself together.

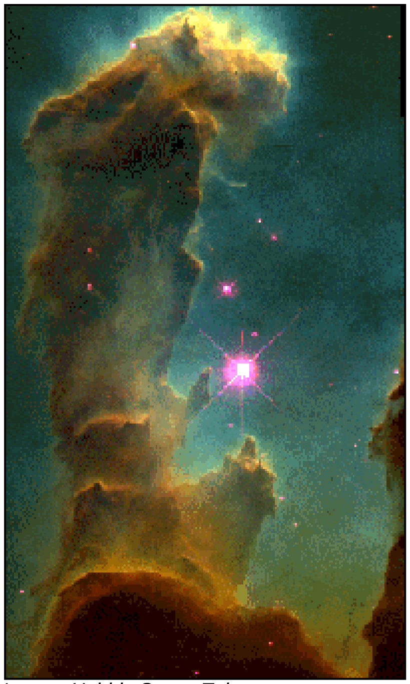

Image: *Hubble Space Telescope*

STAR BIRTHS are started when the interstellar matter in gas clouds, such as the Eagle Nebula shown here, compresses and fuses.

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Answer posted on December 06, 1999

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ASK THE EXPERTS : ASTRONOMY

Images of astronomical nebulae look startlingly like clouds on the sky on the earth, even though they are vastly different in size and composition. Why is this? Are the dynamic processes that shape these cosmic structures the same as those at work in our atmosphere?

Harry Jacobson

Harvard, MA.

James R. Graham, professor of astronomy at the University of California, Berkeley, responds:

"Interesting question! There are similarities between the two, but don't be deceived--terrestrial clouds are very different from interstellar clouds.

"Interstellar clouds are composed mostly of hydrogen, whereas terrestrial clouds are formed from water droplets or ice crystals. Terrestrial clouds come in diverse forms. Take common cumulus clouds as an example. These are the fluffy, white, dome-shaped clouds that have flat bases and wispy tops. A video of the sky played fast-forward shows that cumulus clouds are not static, well-defined entities but rather that they are continually forming, changing shape and dissipating. This restless process occurs because cumulus clouds are created by convective motions of moist air driven by heat from the sun-warmed earth. As a cell of warm air rises, the surrounding atmospheric pressure decreases, allowing it to expand. Expansion causes the air to cool adiabatically (that is, without exchanging heat with the surrounding air) until its temperature declines below the dew point; the air then becomes supersaturated with water vapor. The excess vapor condenses, forming water droplets or, if it is cold enough, ice crystals. Condensation releases latent heat, so the cycle of condensation and convection continues upward until the cell's energy is exhausted. The cell then begins to fall, to be replaced by a new, warm rising cell.

"Water vapor is transparent but water droplets or ice crystals scatter sunlight, making the cloud visible. Therefore, what defines a cloud is not a specific volume of atmosphere, but rather the boundary where a phase transition occurs between vapor and liquid water. This 'dew point' depends on temperature and pressure, which are in turn determined by the motion of the convective cell. Anyone who has watched convection in a vigorously boiling pot of water can readily appreciate the turbulent motions that characterize the process. It is this complexity which leads to the fascinating shapes of cumulus clouds.

"A wide variety of different types of interstellar nebulae and clouds exist. Probably the most familiar are those found in regions of star formation, where the gas is lit up by young stars

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which recently formed out of that gas. Spectacular examples include the Orion Nebula and Eagle Nebula> (the latter was recently the target of a widely seen image taken by the *Hubble Space Telescope*). A kind of phase transition also determines the visible edges of interstellar clouds.

"In regions of star formation, youthful stars inject radiative energy into interstellar clouds, which are primarily composed of hydrogen molecules and hydrogen atoms. Gas close to these stars is illuminated by the young stars' ultraviolet emissions. Ultraviolet rays are sufficiently energetic that they can remove electrons from hydrogen atoms; the resulting zone of ionized hydrogen is called an H II region. The ionized gas in an H II region fluoresces like a neon sign. If the interstellar medium were uniform, then each young star would light up a spherical region of space, but such is not the case. Just as sunlight heating the surface of the earth sets the atmosphere into motion, star formation stirs up the interstellar gas. The ultraviolet light from stars is an important source of heat, and young stars often have outflowing winds or jets of material. When massive stars exhaust their supply of nuclear fuel, they explode as supernovae, releasing titanic amounts of energy. These complex and dynamic phenomena determine the temperature and pressure of gas between stars, and hence the shapes of interstellar clouds.

"The interstellar medium is probably in turbulent motion, just like the terrestrial atmosphere, but the conditions in the interstellar medium are very different from those in the earth's atmosphere. For example, interstellar gas motions are often so violent that velocities exceed the speed of sound, resulting in extreme compression. Consequently, the signatures of turbulence may be very different in these two disparate environments. We can speculate, however, that despite the great differences between nebulae and terrestrial clouds, there are common themes (such as fractal or self-similar geometry) present in the complex behaviors--such as turbulence that occur within these objects. If this inference is correct, it would help account for the broadly similar appearance of terrestrial and interstellar clouds."

Answer posted on October 21, 1999

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Terrestrial clouds seenfrom space

Universityof Illinois Cloud Catalogue

The Web Nebulae

Nebula imagesfrom the Hubble Space Telescope

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September 03, 2003

ASK THE EXPERTS : ASTRONOMY

According to the big bang theory, all the matter in the universe erupted from a singularity. Why didn't all this matter--cheek by jowl as it was--immediately collapse into a black hole?

Michael Bendio

Orem, Utah

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Robert J. Nemiroff, assistant professor of physics at Michigan Technological University, responds:

"First of all, it is not really known whether or not the universe started from a singularity. Our measurements can take us back only so far; ideas about the nature of the cosmos at the start of the big bang are mostly unproved conjecture.

"Second of all, the concept of a black hole is only one type of solution to Einstein's General Theory of Relativity, our best current theory of gravity. This reading of general relativity--known as the Schwarzschild solution--is thought to give an accurate description of the gravity near an isolated, nonrotating black hole, as well as the 'normal' gravity near the earth and throughout our solar system.

"But other solutions to general relativity are known to exist, including ones that apply to a whole universe. These alternative solutions typically assume that the early universe was perfectly uniform so that there were no places for black holes to form, even if the density were so great that particles were 'cheek by jowl.' The most popular class of general relativity solutions applying to the entire cosmos are known as Friedmann-Robertson-Walker solutions. These formulations appear to describe correctly our expanding universe; that is, they demonstrate how objects not held together by local forces (such as the electromagnetism that bonds atoms in molecules or the gravity that keeps the earth intact) stream away from one another in a predictable manner.

"Still, there is room in the theories for some of the matter in the universe to be hidden in black holes that might have formed from local, unusually dense regions in the very early universe. These black holes could conceivably contribute to the large amount of dark matter that exists in the universe. Astronomers are therefore diligently searching for these objects. In one scenario discussed by Jeremiah Ostriker of Princeton University and his collaborators, black holes as massive as one million times the mass of our sun might be common throughout the universe and still be nearly invisible. Although other black holes might come out of some big bang models involving quantum mechanics, a common expectation by cosmologists is that only elementary particles survived these early epochs of our universe."

Christ Ftaclas is an associate professor of physics, also at Michigan Tech. He adds the following:

"The space-time singularity associated with the big bang differs in two important ways from

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the singularity associated with a black hole. First of all, a black hole has an 'outside.' That is, we assume that at large distances from the black hole space-time is essentially flat and defines a background against which we observe the black hole. This is not true in the case of the big bang, because we are all participants.

"The second difference is critical to this question: one of the initial conditions of the big bang is expansion of the matter, whereas a Schwarzschild black hole is associated with a static gravitational field. One might think motion would not make a difference, because no velocity is great enough to escape from a black hole, but that is only true for a particle whose motion is measured relative to the stationary black hole. In the case of the big bang, everything is moving, with the result that the solution to the gravitational-field equations is fundamentally altered."

Nemiroff and Ftaclas recommend these further readings:

Baryonic Dark Matter. Bernard Carr in *Annual Review of Astronomy and Astrophysics*, Vol. 32, pages 531-590; 1994.

Massive Black Holes and Light-Element Nucleosynthesis in a Baryonic Universe. N. Y. Gnedin, J. P. Ostriker and M. J. Rees in *Astrophysical Journal*, Vol. 438, No. 1, pages 40-48; January 1995.

Edward L. ("Ned") Wright is the vice chair for astronomy at the University of California at Los Angeles; he also maintains a thorough on-line Cosmology Tutorial. Wright offers a somewhat different approach to this question:

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Answer posted on October 21, 1999

Related Links:
The Handbook of Space Astronomy and Astrophysics, by Martin V. Zombeck. Cambridge University Press, 1990.
A simpler discussion of the same question from Sten Odenwald's

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ASK THE EXPERTS : ASTRONOMY

How do astronomers measure the distances to galaxies that are millions or even billions of light-years away? I understand that trigonometric parallax can be used to measure distances out to only a couple of hundred light-years away. How do we get from there to the edge of the universe?

Chris Wilhoit
Columbia, Tenn.

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Jay M. Pasachoff is Field Memorial Professor of Astronomy at Williams College in Massachusetts. He sent this answer:

"Trigonometric parallax--the tiny, apparent back-and-forth shifts of nearby stars caused by our changing perspective as the earth orbits the sun--can indeed be used to measure distances only to comparatively nearby stars. Some of the best data on stellar positions in the sky come from *Hipparcos*, a spacecraft launched in 1989 by the European Space Agency. *Hipparcos* has measured the trigonometric parallaxes of about 10,000 stars to an accuracy of better than 10 percent, out to a distance of about 300 light-years. But our galaxy is about 100,000 light-years across, so parallax measurements become useless long before we approach the distances to other galaxies.

"The traditional way to measure distances to nearby galaxies is by studying variable stars, especially a type of bright variable star known as a Cepheid variable. Early in this century Henrietta Swan Leavitt discovered that the longer the period of variation of a Cepheid variable, the greater its luminosity. Another American astronomer, Harlow Shapley, then was able to correlate the brightnesses of Cepheids with those of known types of ordinary stars, tying Leavitt's relative distance scale to an absolute one. Thus, we can observe a Cepheid, note how long it takes for its brightness to vary and plot that information on an already established graph to find out its intrinsic luminosity. Comparing this true brightness (its 'absolute magnitude') with its apparent brightness as seen in the sky (its 'apparent magnitude') allows us to calculate how far away it is, using the inverse-square law of brightness. "Fortunately, Cepheids are luminous enough that they can be observed in other galaxies, not just in our own. In the 1920s Edwin Hubble used the period-luminosity relation for variable stars to establish the distances to various galaxies and proved that they lie far outside our Milky Way. In the course of that work, he discovered what we now call 'Hubble's law,' that galaxies display a linear relation between distance and redshift (the redshift is the shift in the positions of lines in the galaxies' spectra toward the red end of the rainbow). Hubble's law is the basis for the modern understanding that we live in an expanding universe. After measuring the redshift, which we can do by passing a galaxy's light through a spectrogram, we can deduce the distance using Hubble's law. This technique is the astronomer's basic tool for finding the distances to the farthest things in the universe.

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"But of course there are many complications. Maybe the relation between redshift and distance is not quite linear when we get very far out in the universe. Maybe there are giant concentrations of mass that distort what is otherwise thought to be a smooth, outward expansion, or 'Hubble flow.' Maybe the expansion of the universe inferred by Hubble is accelerated by a 'cosmological constant' in Einstein's equations, the solutions of which are the basis for theoretical cosmology. And measurements of the rate of the cosmic expansion remain controversial. The *Hubble Space Telescope* is in the process of observing a large set of Cepheid variables in distant galaxies in order to resolve this question.

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"Cosmologists are also turning their attention to other bright objects that can be seen at great distances as a way of verifying the accuracy of their measurements. A certain kind of exploding star, or supernova (called a Type Ia supernova), always seems to have the same peak luminosity, so these supernovae can be used as 'standard candles' instead of Cepheids. Supernovae are billions of times brighter than Cepheids; as a result, they can be observed at far greater distances. A number of researchers are trying to exploit this advantage and get more accurate information about the size and age of the universe. The *Hubble Space Telescope* is assisting in this work as well.

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ASK THE EXPERTS : ASTRONOMY

How do we know that distant galaxies are composed of matter rather than anti-matter? If equal quantities of each were produced in the big bang, might not some parts of the universe contain primarily matter and other parts primarily anti-matter?

Mark H. Zellers

Mountain View, Calif.

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Steve Naftilan of the Joint Science Department at The Claremont Colleges answers:

"When matter and antimatter meet, they annihilate each other and the mass is converted into energy--specifically, into gamma-rays. If a distant galaxy were made of antimatter, it would constantly be producing gamma-rays as it encountered the matter in the intergalactic gas clouds that exist throughout galaxy clusters.

"We do not see any steady stream of gamma-rays coming from any source in the sky. Therefore, astronomers conclude that there are not occasional 'rogue' galaxies made of antimatter. If there is any large amount of antimatter in the universe, it must encompass at least an entire galaxy cluster, and probably a supercluster. Once might postulate the existence of such antimatter superclusters, but then one would be faced with the problem of coming up with a mechanism that, shortly after the big bang, would have separated these now-gigantic clumps of antimatter from the neighboring clumps of mater. No such mechanism has yet been envisioned."

>Scott Dodelson is a scientist in the Theoretical Astrophysics Group at Fermi National Accelerator Laboratory. He offers a more detailed reply:

"The question of whether or not there is anti-matter in the universe has been around ever since the prediction of the existence of the anti-proton early this century. For reasons that I'll explain, most physicists don't believe there is much anti-matter around. But the fact that the question is still being asked (by many scientists) indicates that it has not been definitively answered. We may all be in for a big surprise!

"With that background, here is an overview of our present thinking. A simple way to test and see if there is anti-matter around is to send out a 'detector.' In this case, it is completely trivial to make a detector: it simply has to be made of matter! Any time matter collides with anti-matter, the two annihilate and produce lots of gamma rays. We have sent spacecraft to Jupiter and other planets. These objects didn't annihilate, so we know that our solar system does not contain much anti-matter.

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"In fact, we can make a much stronger statement about the abundance of anti-matter by searching for gamma rays from other galaxies and clusters of galaxies. A typical cluster does not emit many gamma rays, so all the galaxies in it must be made solely of matter. It is possible that all the galaxies in a given cluster are made of matter while all those in another are made solely of anti-matter. If this were true, then there would be immense gamma radiation coming from the boundary regions between clusters of different types. At present, such radiation is not observed, a fact that again argues against this separation. Matter and anti-matter therefore must be separated on scales larger than cluster sizes (roughly ten million light years).

"There is a strong argument against the possibility that matter and anti-matter exist in equal numbers in our universe but are for some reason separated. This argument goes back to the early universe and asks, When must the matter and anti-matter have been separated? It must have been very early, when the temperature of the universe was roughly 500 billion Kelvins. If they hadn't separated by then, matter and anti-matter would have mutually annihilated, because the universe was very dense. Is it possible to think of a mechanism that separated matter from anti-matter when the universe was very hot and dense? Apparently not, for any way of separating them has to obey causality. Early in the history of the universe, when annihilation between matter and anti-matter was occurring, the farthest possible distances that were in causal contact with each other were about 100 kilometers. This size is a billion times smaller than the regions that would grow to be clusters. So it seems impossible that matter was separated from anti-matter on scales the size of clusters today. The most natural explanation is that the universe is made up only of matter and contains no large reservoir of anti-matter. In fact, there are theories which explain how such an asymmetry could have occurred.

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ASK THE EXPERTS : ASTRONOMY

How do we know that distant galaxies are composed of matter rather than anti-matter? If equal quantities of each were produced in the big bang, might not some parts of the universe contain primarily matter and other parts primarily anti-matter?

Mark H. Zellers
Mountain View, Calif.

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"Having said all this, I want to reiterate that this is not the final word. The arguments I have presented are suggestive but not compelling. For this reason, some physicists are excited about the Alpha Magnetic Spectrometer, a device that the National Aeronautics and Space Administration wants to fly in the Earth's orbit that will look directly for anti-matter."

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ASK THE EXPERTS : ASTRONOMY

Is the violent behavior of quasars caused by black holes in galaxies? If so, does the discovery of black holes in the centers of many normal galaxies mean that all galaxies were once quasars?

Bruno Navert
Varennes, Quebec, Canada

Roeland van der Marel of the Institute for Advanced Study in Princeton, N.J., has been investigating this question. He responds:

"Quasars were discovered in the 1960s. The name is a contraction of 'quasi-stars' or 'quasi-stellar object,' which refers to the fact that quasars are generally point sources (like stars) that have no observable extent. The radiation from quasars is greatly stretched, or redshifted, which implies that these objects are very far away--the stretching of their light is presumed to result from the overall expansion of the universe. To be visible to us despite their tremendous distances, quasars must produce a tremendous amount of energy, yet they must be small enough to appear pointlike.

"Some galaxies contain very bright, compact regions in their centers; these objects are known as active galaxies. Quasars have spectral properties that are very similar to those of the central regions of these active galaxies. Astronomers have therefore long believed that quasars are galaxies in which only the bright nucleus can be seen. Recent observations with the Hubble Space Telescope have confirmed this hypothesis: high-contrast images clearly show, for the first time, the galaxies within which quasars are embedded.

"The most plausible mechanism that could produce the vast energy output of both quasars and active galaxies is the accretion of matter onto a massive black hole. As gas falls into the black hole, it forms a disk that grows extremely hot because of friction; this process releases energy in accordance with Einstein's equation $E = mc^2$. This standard model of how quasars work is supported by very convincing evidence indicating the presence of massive dark objects in the nuclei of some active galaxies. As a result, a substantial majority of professional astronomers is convinced that the violent behavior of quasars is indeed caused by black holes.

"Now onto the second part of the question, 'Does the discovery of black holes in the centers of many normal galaxies mean that all galaxies were once quasars?' Nearly all quasars are seen at high redshifts. Hence, we see them when they were still very young: they are very distant, so their light took a very long time to reach us. In the current epoch, quasars are extremely rare. Quasars therefore must evolve into something else that we do see in large abundance today (that is, in the relatively nearby portion of the universe). The most likely objects that they evolved into are normal, quiescent galaxies. If this is the case, then normal galaxies should still have massive black holes in their nuclei, like quasars, but these black holes should now be starved of fuel.

"Observations of several normal galaxies, including our own Milky Way, have provided evidence for the presence of such black holes. What we do not yet know is what fraction of all normal galaxies once passed through a quasar phase. To answer that question, we need high-spatial resolution spectroscopic observations of a large sample of 'normal' galaxies, which would reveal the presence of massive central black holes. This kind of information can now be obtained using the STIS spectrograph, which was recently installed by NASA astronauts on the Hubble Space Telescope. Several groups will try to answer the question in the coming years."

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ASK THE EXPERTS : ASTRONOMY

According to the big bang, space itself is expanding. I don't understand: If space is expanding, into what is it expanding?

B. C. Dozier

Kerrville, Tex.

Joel R. Primack, a cosmologist at the University of California at Santa Cruz, notes that the big bang involves physical processes quite unlike those of everyday experience. For that reason, people often find it quite difficult to grasp what astronomers mean when they refer to an Rexpanding universe.

One common misconception, Primack says, is "that the big bang is an explosion that occurred at some point in a preexisting static space--which is not a picture in accord with our modern theory of space-time and gravity." He explains why this image of the big bang as an explosion in space, like the detonation of a bomb, is incorrect:

"According to modern cosmological theory, based on Einstein's General Relativity (our modern theory of gravity), the big bang did not occur somewhere in space; it occupied the whole of space. Indeed, it created space. Distant galaxies are not traveling at a high speed through space; instead, just like our own galaxy, they are moving relatively slowly with respect to any of their neighboring galaxies. It is the expansion of space, between the time when the stars in these distant galaxies emitted light and our telescopes receive it, that causes the wavelength of the light to lengthen (redshift). Space is itself infinitely elastic; it is not expanding into anything."

The lengthening, or redshifting, of light that Primack describes was first observed by Edwin Hubble in 1929. This phenomenon is often referred to, incorrectly, as a Doppler shift. A Doppler redshift results from the expansion of light emitted by a receding object. Cosmological redshifts result from the expansion of space (and the light moving through that space) between us and a distant galaxy or quasar. Space is expanding everywhere, so the more distant an object is, the more rapidly it appears to be moving away.

Primack then considers another aspect of the reader's question: What lies beyond our cosmic horizon, the visible "edge" of the universe?

"Every observer in the universe is surrounded by a sphere beyond which nothing can be seen: the observer's cosmic horizon (the point at which the apparent recessional velocity equals the speed of light). Because it is the expansion of space rather than the high velocity of distant galaxies that prevents us from seeing beyond our cosmic horizon, there is no reason to suppose that galaxies outside it are any different from those inside it. Indeed, the extreme isotropy, or smoothness, of the cosmic background radiation (it appears to have the same temperature in all directions, to about one part in 100,000), together with the law of General

Relativity and other physical assumptions that seem reasonable, implies that the universe must remain pretty much the same out to a considerable distance beyond our horizon.

"The theory of cosmic inflation, a recent elaboration of the big bang, suggests that at still greater distances, the universe is very different from the way it is locally. Although we cannot check this prediction directly, other predictions of inflation are being tested by new observations, especially those to be made by the astronomy satellites that NASA and the European Space Agency plan to launch in the next five to 10 years. There are many books that discuss current theories of the expansion of the universe and related topics. Of these, my favorite one is Cosmology, by Edward R. Harrison (Cambridge University Press, 1981)."

Takamasa Takahashi of St. Norbert College adds a few comments:

"Many scientists do not ask 'What came before the big bang?' because it is beyond the scope of our physical theories. Usually we consider the big bang to be the beginning of time and space, and so it is meaningless to ask what existed before or what lies beyond the expanding universe. Because space itself is intimately connected with matter in the universe, as matter was created in the big bang, so was space. There is no 'empty space' that the universe is expanding into.

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ASK THE EXPERTS : ASTRONOMY

Astronomers have now discovered about 10 planets orbiting other stars. When and how will these planets receive names? Who gets to name them?

M. Daniel Blair
Washington, D.C.

After years of fruitless searching astronomers have been delighted and a little astounded by the rapid pace of discovery of planets around nearby stars. Thee first of these, around the star 51 Pegasi, was found just in October 1995. There is now strong evidence for planets circling at least eight sunlike stars. (The exact number depends on how much faith one puts in some tentative observations and on whether one classifies certain extremely massive bodies as true planets; the Extrasolar Planets Catalogue maintains a frequently updated list of the various candidates.) Such swift progress has caught the scientific community off guard, so there is as yet no standard set of rules for naming the new planets.

Geoffrey Marcy of San Francisco State University leads the team that has produced most of the new discoveries. He provides this insider's view of the current ferment:

"Formal names of astronomical objects and features are set by the International Astronomical Union (IAU). At the meeting of the IAU General Assembly in Kyoto, Japan, in August 1997, there will be a convening of the IAU's Naming Commission. The commission is the body that normally is responsible for assigning names to new asteroids, craters and so on. At the Kyoto meeting, the IAU will bring up the issue of naming new planets around other stars.

"The issue of extrasolar planet names has become quite pressing. For example, William D. Cochran of the University of Texas and our group at San Francisco State recently announced the discovery of a planet orbiting the star 16 Cygni B (a sunlike star roughly 70 light-years distant in the constellation Cygnus). What should we call this planet? We cannot call it ' 16 Cyg B b.' And we certainly cannot call it '16 Cyg A,' because 16 Cyg B already has a stellar companion by that name. We cannot call it 16 Cyg C (which would seem to denote a third star in the system); even '16 Cyg 3' or '16 Cyg B 2' seems too cumbersome and nondescript. So some uniform naming system is needed.

"Assigning Greek names, akin to the ones we use for the planets of our own solar system, would be fine, but it would not constitute a coherent naming system per se. Likewise we could designate the planets using lowercase Roman numerals after the name of the star, but that system is also very bland and does not work well verbally. In retrospect, simply using numbers to denote planets might be adequate--'16 Cyg B 2,' as suggested above, might be okay. But, of course, the first planet discovered around a star might not be the closest one nor the biggest one. Perhaps we could number the planets as they are found; then centuries from now, when the planetary inventories are more complete, someone could rename them all, just as Scarlatti's sonatas were renumbered years later, putting them in correct order.

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ASK THE EXPERTS : ASTRONOMY

How do scientists determine the ages of stars? Is the technique really accurate enough to use it to verify the age of the universe?

Carol Phillips
Lubbock, Texas

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Stephen A. Naftilan, professor of physics in the Joint Science Department of the Claremont Colleges, responds:

"Astronomers usually cannot tell the age of an individual star. There are certain stars that we know are very young, and others that are very old, but for most stars we cannot tell. When we have a large group of stars, however, we can tell its age. This is possible because all of the stars in a cluster are presumed to have begun their life at approximately the same time. After a relatively brief time (in 'star time,' that is--we are talking thousands to millions of years here) stars reach the adult phase of their life, which we call the main sequence phase. The length of time a star spends in the main sequence phase depends on its mass.

"Constructing a plot, called the HR diagram, of the stars in the cluster, scientists can determine the mass of the stars that are just ending this phase and moving on to the next phase of their life, the red giant phase. Computer models allow us to predict how old a star of that mass must be to be at that juncture of its life, and hence to estimate the age of the cluster. Recently, this procedure has come under close scrutiny because that age it gives for the oldest star clusters in our Milky Way seems to be older than the age of the universe derived from the most recent Hubble Space Telescope data."

Peter B. Stetson, senior research officer at the Dominion Astrophysical Observatory in Victoria, British Columbia, provides a more detailed reply:

"It is impossible to determine the age of a single star all by itself. The only real means we have to determine stellar ages is through the study of star clusters. In our galaxy, the Milky Way, there are two basic types of star cluster. Clusters of the first type are called 'globular clusters' because they appear as huge, round globs containing anywhere from a few thousand to a few million stars. Globular clusters are very old, and they are scattered around (not just within) the Milky Way; these clusters seem to have originated near the time our galaxy started to form, when the universe was quite young. Clusters of the second type used to be called 'galactic clusters' because we see them inside the body of our galaxy, but now it is more common to refer to them as 'open clusters' because they are much looser and their stars more spread out on the sky than are those in globular clusters. Open clusters can contain anywhere from a few dozen to a few thousand stars, and they come in a wide range of ages. Apparently our galaxy started making open clusters soon after it settled down to its present size and continues making them even today.

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"The stars in either type of star cluster were all formed at the same time and out of the same material. The essential feature of a star cluster that lets us estimate its age is that each cluster contains stars with a range of masses. When a cluster is born, it will contain many stars of about the same size and mass as our sun, but there will also be numerous stars more massive than our sun and many other stars less massive than our sun. For about 90 percent of its lifetime, a star shines because nuclear reactions are converting hydrogen to helium in the star's center, releasing vast amounts of energy. This energy works its way from the center of the star to the surface and escapes the star in the form of light. The more massive a star is, the bigger the furnace in the center, and the brighter and the hotter the star is in this stable stage of its life. The most massive stars are very bright and blue-hot; a less massive star is somewhat fainter and white-hot; a star like our sun is a bit fainter still and is yellow-hot; and the least massive stars are very faint and merely red-hot. During this period of its life, a star hardly changes either in brightness or in temperature.

"The duration of the stable, or 'main sequence,' phase depends on a star's mass. A star 10 times as massive as the sun contains, clearly, 10 times as much fuel. It consumes that fuel roughly *10,000* times faster than the sun, however. As a result, it has a total lifetime 1,000 times shorter than that of our sun. When the hydrogen fuel in the center of a massive star is exhausted--'the center' representing about 10 percent of the star's total mass--it becomes increasingly unstable. The star remains bright, but it quickly switches from being comparatively small and hot to being huge and red for a while, then it briefly becomes smaller and bluer, then even larger and even redder, and finally explodes as a supernova, spewing its nuclear ashes as well as its unburned fuel back into space. Similarly, a star five times more massive than the sun has a lifetime roughly 100 times shorter than the sun before it becomes unstable and ends its active life. A star like our sun is calculated to have a total stable life-span of around 10 billion years; the sun is now a bit less than half that age (this age is very accurately determined from radioactive elements in meteorites), so we have another five billion years or so before we have to start looking for a new home.

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Carol Phillips
Lubbock, Texas

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"In the case of a single star, its brightness and temperature don't tell us much. Because these properties stay fairly constant for 90 percent of its lifetime, the star could be fairly young or fairly old, and we wouldn't be able to tell the difference. In a star cluster, we have the advantage that stars of all masses formed at about the same time. So all we have to do is look at the cluster and determine how hot and how massive is the hottest, bluest, most massive star that has not yet entered the late, unstable period of its life. The star's mass tells us how much fuel the star had when it was born, and the star's brightness tells us how fast it is burning that fuel. We know that the star is just about to start becoming unstable--after all, the stars that are more massive have already started to become unstable. We also know that its fuel is just about exhausted. The ratio of how much fuel the star had in the beginning to how fast it has been burning that fuel tells us how long the star has been alive. (By analogy, if we know how much kerosene our hurricane lamp contained when we lit it and how fast it consumes the kerosene, and if the lamp is just now starting to go out, then we can deduce how long it has been lit.) Because all the stars in the cluster are the same age, the age of that one star tells us the age of the entire cluster.

"The basic physics of how hydrogen is converted to helium in the centers of stars and the amount of energy generated by this process is comparatively simple and well understood. For much of the 20th century, the main limitation to our knowledge of stellar ages has been due to the difficulty of measuring the distances to the clusters--especially the distances to the oldest clusters, the globulars, which are comparatively far away. (We know how bright a star looks, but to know how bright it really is, you have to know how far away it is: is it like a headlight a mile away or an airport beacon 10 miles away? In the dark of the nighttime sky with no reference points, it's pretty hard to tell.) Technical advances, such as the introduction of charge-coupled devices to replace photographic plates for the measuring of stellar distances and brightnesses, are making our observations more secure.

"Distance measurements have improved to the point at which other details needed to determine the ages of star clusters--such as the fine details of how a star converts nuclear energy to visible light--can no longer be ignored. How exactly does the energy get from the center of the star, where it is generated, to the surface, where it becomes the light that we see? How important is convection as a means of transporting energy, and how efficient is the convection? The answer to these questions has some effect on the inferred relationship between mass and surface temperature. Just how much oxygen is in the stars, along with the hydrogen and helium? The relative amount of oxygen present has a modest effect on the efficiency of the central furnace, affecting the relation between mass and brightness and, hence, age.

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"Taken together, the uncertainty in the observations and the uncertainty in the relevant theoretical physics probably lead to an uncertainty of 10 percent to 20 percent in our estimate of the absolute ages of the globular clusters. According to our best available estimates, stars having about 90 percent of the sun's mass are just now starting to die in the globulars. These stars are most probably around 15 billion years old, but they could conceivably be as young as 12 billion years or as old as 18 billion years. It is very unlikely that most of them could be either younger or older than this range. This estimate is already accurate enough to place some very interesting limits on the age and life history of the universe."

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ASK THE EXPERTS : ASTRONOMY

Why are scientists so sure that the Martian meteorite that has been in the news recently really came from Mars? Couldn't it have been dislodged from Earth by an asteroid impact and then returned millions of years later? Couldn't the early Earth (or some distant asteroid) once have been chemically similar to Mars?

Pete Stafford

Atlanta, Ga.

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Several readers have asked versions of this question. David W. Mittlefehldt of the NASA Johnson Space Center considers the second part of the question, why astronomers are so sure that the "Martian" meteorite did not really originate on Earth:

"There are numerous reasons why ALH 84001, the meteorite that contains possible fossil evidence of early Mars life, cannot be a fragment of Earth that was blasted into space and reaccreted after a sojourn of about 16 million years in space.

"Perhaps the most conclusive evidence lies in the mix of oxygen isotopes (versions of the same element having different atomic masses). All oxygen is composed of three naturally occurring isotopes of masses of 16, 17 and 18. Chemical processes that occur on planets and in space can partially separate, or fractionate, the different isotopes, and the amount of fractionation varies directly with the difference in mass. That is, the amount of fractionation of oxygen 18 from oxygen 16 is twice the fractionation of oxygen 17 from oxygen 16. All oxygen on Earth follows the same fractionation pattern, be it in a rock, a snowflake, the air we breathe or the nail clippings from your big toe.

When one measures the isotopic composition of meteorites, however, it turns out that most meteorite groups do not lie on this terrestrial fractionation line; they have either excesses or depletions in oxygen 16 as compared with Earth rocks with the same oxygen 18 content. There is no chemical process that can explain this difference, so the meteorites must have formed from material that had an oxygen isotopic composition distinct from that of the material that went into making Earth. The meteorites from Mars, including ALH 84001, are different from all Earth materials in oxygen isotopic composition and so cannot have come from Earth.

"There are other reasons to discount Earth as the parent of ALH 84001. Isotope ratio measurements show that the nitrogen in ALH 84001 is very 'heavy': it contains much more of the mass 15 isotope relative to the mass 14 isotope than does our atmosphere. Similarly, hydrogen in ALH 84001 is much 'heavier' (enriched in deuterium) than hydrogen found in terrestrial rocks. So-called noble (unreactive) gases trapped in meteorites are thought to be atmospheric gases that were trapped in the meteorite by the impact process that launched them off their parent body. The heavy noble gases, particularly xenon, trapped in ALH 84001 are distinct in isotopic composition from xenon in Earth's atmosphere but are similar to that in the Martian atmosphere. ALH 84001 contains carbonate minerals; the carbon in the carbonates is also enriched in the heavy isotope compared to that in terrestrial carbonates. Hence, the composition of ALH 84001 is distinctly nonterrestrial.

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"Finally, there are some purely geologic reasons why ALH 84001 cannot be from Earth. The crystallization age of ALH 84001, though not precisely known, is about 4.5 billion years. This is much older than that of any known Earth rock (the oldest known are on the order of 3.9 billion years old). While in space, rocks are exposed to cosmic rays, high-energy particles. The cosmic-ray exposure age of ALH 84001 is about 16 million years, which means that it was launched off the surface of its parent object 16 million years ago. It would take a huge impact, which would produce a large crater, to launch a rock off Earth. No craters of sufficient size of that age are known on Earth. (ALH 84001 cannot have come from the ocean floor, where a crater might have gone undetected, because nowhere is the oceanic crust older than about 200 to 250 million years.)

"Although there are few things in science that can be said with absolute, 100 percent certainty, this is one of them. ALH 84001 is not an Earth rock."

Richard N. Zare of Stanford University, one of the co-authors of the paper describing possible fossil life in the Martian meteorite, introduces the next part of the story: how scientists came to think that the rock came specifically from Mars:

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Atlanta, Ga.

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"When I was a graduate student, the conventional wisdom was that meteorites derived only from asteroids, not from the moon or other planets. We did not consider the possibility that the impact of a large body--an asteroid or a comet--could blast chunks of rock free from a planet into orbits around the sun, where they could one day land on Earth. In 1981, however, scientists determined that a meteorite found in Antarctica must have originated on the moon: its composition exactly matched that of the lunar samples brought back by the Apollo astronauts. So much for what I had been taught!

"Only a few years later, another Antarctic meteorite was found to be from Mars. This conclusion was based on the close match between the concentrations of various gases trapped inside the meteorite and the concentrations of those gases in the Martian atmosphere, as measured by the two *Viking* lander missions to Mars in 1976. The evidence was strong enough that researchers studying meteorites quickly became convinced, by and large, that we had in our possession a meteorite from Mars. Since then, about dozen other such Martian meteorites have been identified."

Harry Y. McSween of the University of Tennessee expands on this story:

"The Martian meteorite belongs to a class known as the SNC (shergottite-nakhlite-chassignite) meteorites. The first hint that these objects are fragments not of asteroids but of a large planet came from the determination that all but one of them formed relatively recently by solar system standards. These meteorites are igneous rocks; measurement of radioactive isotopes in them gives the times at which the magmas solidified. Their ages (1.3 billion years or younger) are too young for igneous activity on small bodies like asteroids, because such bodies cannot long retain the heat generated by slow decay of radionuclides. Large planets can retain this heat, however, because rocks are poor conductors of heat, and heat loss through great thicknesses of rock would require many billions of years. Of course, this line of argument only indicates that the SNC meteorites came from a large body (that is, a planet), although Mars seemed a plausible choice.

"A more direct link between SNC meteorites and Mars is based on the gases implanted in the

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meteorites. The shergottite rocks in particular were heavily shocked by meteor impacts when they were on their parent planet, and some of them contain pockets and veins of solidified impact melt (glass). Bubbles trapped in the glass provide tiny samples of the ambient atmosphere; analysis of the gases in the bubbles reveals that they rather precisely match the composition of the Martian atmosphere as measured by *Viking* landers. This atmospheric composition is very unusual, so it serves as a chemical fingerprint to tie these meteorites uniquely to Mars.

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"Not all of the SNC meteorites are sufficiently shocked to contain trapped Martian atmosphere, but all share other chemical characteristics (such as their oxygen isotope compositions) that link them together as specimens from the same planet. The ALH 84001 meteorite, the one in which the possible signs of fossil life have been found, is much older than the other SNC samples, but it shares with them these other chemical characteristics."

And Michael E. Lipschutz, professor of chemistry and director of chemistry operations at the PRIME Lab at Purdue University, provides this detailed overview:

"There are 12 known Martian meteorites, six of which fell elsewhere on Earth before 1969, when the first major meteorite recoveries began from Antarctica. (One of the six is the only one known to have caused a fatality: a piece hit and killed a dog when it landed in Egypt in 1911!) Most Martian meteorites have comparatively young crystallization ages of 1.3 billion years or less. The crystallization age of a meteorite is the time elapsed since its constituent solid materials crystallized from molten silicate magma. Such young crystallization ages imply a large parent planet, because only large objects can develop and retain for several billion years the high temperatures necessary to form magmas. Asteroids would have cooled down very shortly (less than 100 million years) after the solar system formed 4.55 billion ago, so such objects could not have produced the Martian meteorites. (Interestingly, ALH 84001 has an old crystallization age of 4.5 billion years, much older than the other Martian meteorites.)

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September 03, 2003

ASK THE EXPERTS : ASTRONOMY

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Why are scientists so sure that the Martian meteorite that has been in the news recently really came from Mars? Couldn't it have been dislodged from Earth by an asteroid impact and then returned millions of years later? Couldn't the early Earth (or some distant asteroid) once have been chemically similar to Mars?

Pete Stafford
Atlanta, Ga.

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"To escape from a planet, a rock must be propelled outward by a fast-moving, large projectile (of asteroidal or cometary origin) whose impact results in an explosion. The velocity of material that is ejected by the explosion depends on the pressure to which the material is shocked: the higher the pressure, the higher the shock velocity. But the shock temperature also increases with shock pressure. The maximum velocity that silicate material can acquire by shock, yet remain unvaporized, is about five kilometers per second--which happens to be approximately Martian escape velocity (or the speed required for an object to go from Mars's surface to infinite distance). Earth's escape velocity, in contrast, is 11 kilometers per second, so it is essentially impossible to shock silicate strongly enough to free it from Earth without vaporizing it at the same time.

"Although people began to think years ago that the SNC meteorites came from Mars, there was one critical question unanswered: Why weren't there known lunar meteorites? The moon is closer to Earth than Mars is, after all, and the escape velocity of the moon is just 2.4 kilometers per second. That question disappeared in 1981 and 1982, when the first of a dozen lunar meteorites was discovered in Antarctica.

"The 12 Martian meteorites are genetically linked to one another by the isotopic composition of oxygen in their minerals. The relative amounts of stable oxygen 16, oxygen 17 and oxygen 18 in planetary samples apparently reflect the amounts present in that part of the presolar nebula (the cloud of gas and dust) from which their solid parental material condensed. On an appropriate oxygen isotope plot, terrestrial and lunar rocks define one trend line, Martian meteorites another, and other meteorite types still others.

"The chemical compositions of Martian meteorites seem generally similar to the compositions of Martian rocks determined by the two *Viking* landers in 1976. The *Viking* results have large uncertainties, however. The compositional evidence that I find most convincing relates to the elemental and isotopic contents of the Martian atmosphere measured by *Viking*. The

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corresponding contents in Earth's atmosphere are known much more precisely. Samples of shock-produced glass in one of the Antarctic Martian meteorites contain gases whose elemental and isotopic compositions seem to represent a mixture of terrestrial and Martian atmospheres. It is thought that Martian atmospheric gases were trapped in the glass when it formed from silicates by shock during an impact on the Martian surface. After the meteorite landed on Earth, some terrestrial atmospheric gas leaked in.

"I think that every experienced planetary scientist today accepts the Martian origin of these 12 meteorites. They are currently being studied intensively to obtain information about Mars; only when we have planetary samples in our laboratories can we study them with the sophisticated equipment and techniques necessary to answer fundamental questions about their genesis and history. Whether they contain evidence for alien life is an excellent example of such a question."

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Can you explain how jet propulsion engines work?

Gareth Young,
Buckley, Flintshire, England

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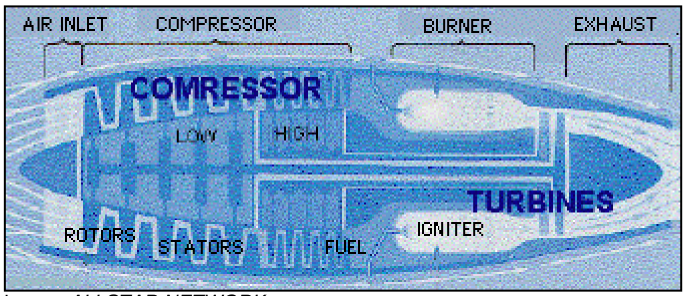

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TURBOJET ENGINES--which, like ramjet engines, must support supersonic flight--are less fuel-efficient than turbofan engines, which are used in modern commerical aircraft.

Above a certain altitude the atmospheric density diminishes and jet propulsion is only possible for rocket engines that carry their own oxygen. Rocket motors use either solid or liquid fuels. Solid rockets are the oldest types, and their bodies contain the combustion chamber and the solid fuel mixed with oxidizer. When the fuel is ignited the gaseous products of combustion are accelerated through the nozzle to produce thrust. In liquid rockets, the fuel and oxygen are stored in separate tanks and fed at controlled rates to the combustion chamber.

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Can you explain how jet propulsion engines work?

Gareth Young,
Buckley, Flintshire, England

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Awatef Hamed, Professor of Aerospace Engineering and Engineering Mechanics at the University of Cincinnati, provides this explanation:

Awatef Hamed

Jet propulsion revolutionized the science of flight by dramatically increasing possible speeds and altitudes, hence enabling space exploration. The term jet propulsion refers to the action produced by a reactor to the ejection of matter. For example, when the matter in a typical rocket (like gunpowder in fireworks) is ignited, the resulting chemical reaction produces heat and gases, which escape from the rocket and cause it to move forward. The oxygen necessary for combustion is carried (in tanks or in a combined form) in the rocket itself so that the rocket thrust is independent of the atmosphere. Other jet propulsion devices depend on the air inducted into the engine to supply the necessary oxygen. After heat is released by the combustion, the hot gases are accelerated through the engine so that the exit velocity is greater than the airstream velocity at the entrance.

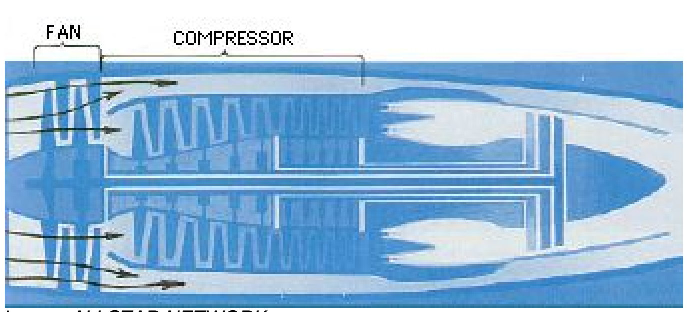

Image: *ALLSTAR NETWORK*

TURBOFAN ENGINES eject rearward a large mass of material at a low velocity to produce forward thrust.

In both self-contained rocket motors and air-breathing jet propulsion power units, the thrust that can be generated is proportional to the mass of material ejected from the unit in a given

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time, as well as the increase in the mass velocity with respect to the unit. Therefore, the same forward-thrust force can be produced in two ways: by ejecting rearward either a large mass of material at a low velocity during a given time period (as in turbofan engines) or by ejecting a smaller mass of material at higher velocity (as in turbojet and ramjet engines). The two sources of mass are the propellant, or fuel, and the oxidizer, or air.

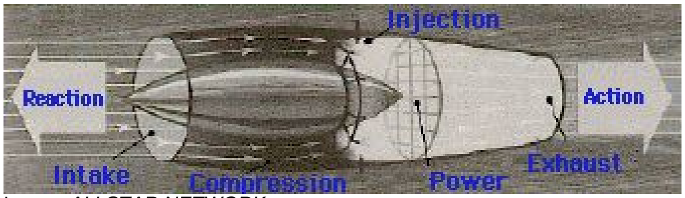

Image: *ALLSTAR NETWORK*

RAMJET ENGINES produce thrust by ejecting a smaller mass of material at higher velocity than do turbofan engines.

Fuels contain a large quantity of potential energy, which is rapidly released during combustion. A portion of this heat energy is converted into useful work, moving the vehicle through the atmosphere or into space. Another portion, however, in the form of the jet's kinetic energy, is lost and dissipates into the atmosphere. The very fuel-efficient turbofan engines used in modern commercial aircraft engines attempt to minimize the latter portion. To do so, they impart a moderate increase in the mass velocity to the combustion products for the large mass of air drawn through the engine in a given time. But turbojet and ramjet engines, which meet more demanding supersonic flight requirements, are less fuel-efficient.

Various types of jet engines have been developed to deliver the required thrust and engine performance for a wide range of flight speeds and altitudes. Air-breathing turbojet, turbofan and ramjet engines operate according to similar principles in the sense that they raise the inducted air pressure before combustion and expand the high-energy gases before they leave, in a nozzle or exhaust system. In turbojet engines, the inducted air goes through a compressor to increase its pressure before entering the combustor, then through a turbine before accelerating in the exhaust nozzle. The ramjet engine, though, has no moving parts; it produces a ram pressure rise from decelerating the high-speed inducted air in the inlet diffuser. The ramjet engine can only operate at high supersonic velocities and therefore requires another launching device, such as a rocket or turbojet engine, to accelerate it to the required speed.

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September 19, 2003

ASK THE EXPERTS : ASTRONOMY

How do planets acquire rings?

J. Cook,
No address given

Astrophysicist George F. Spagna, Jr., of Randolph-Macon College provides this explanation:

The bright rings of Saturn have puzzled scientists ever since Galileo first observed them in about 1610. He initially thought of Saturn as a triple planet because he could discern only two irregular blobs of light, one on either side of the planet itself. Then in 1655 Christian Huygens proposed that these blobs were actually a flattened system of rings circling the planet above its equator.

We now know that rings circle all four of the gas giant planets in our solar system—Jupiter, Saturn, Uranus and Neptune—though only Saturn's are obvious when viewed from Earth. Contrary to their appearance, they are not solid rings or disks at all. Rather they are composed of myriad bits and pieces of ice, rock and dust. In the case of Saturn's brightly visible rings, they consist of more ice, which reflects sunlight effectively. The rings of the other planets contain mostly dust, which is dark and doesn't reflect much light. Additionally, whereas Saturn's rings are wide, the other planets sport thin rings.

The rings of Jupiter, Uranus and Neptune probably arose as a result of meteor impacts on their tiny inner satellites. Dust and rocky debris blasted off the satellites' surfaces continues to orbit the planet for many years. Indeed, we have observational evidence from the Galileo space probe, currently orbiting Jupiter, that traces the ring material directly to three of the smallest inner satellites—the rings are even in similar orbits. Saturn's rings probably represent a moon-shattering collision that left debris from an icy moon too close to the planet to reassemble. Of interest, Earth is acquiring its own "ring system" of space junk and debris from old satellites and launch vehicles.

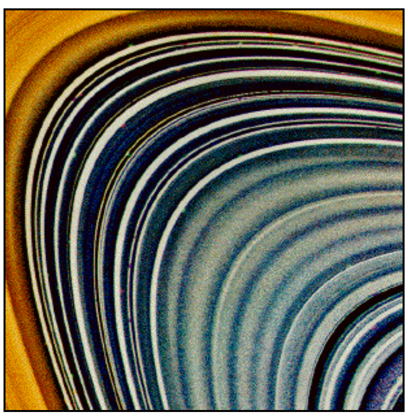

Image: *JPL/NASA*

SATURN'S RINGS, as photographed by Voyager 2, show that the C ring (*blue*) and the B ring (*yellow*) contain traces of different elements.

The rings most likely have minimal effect on the planets, except perhaps as a reservoir for "shooting stars" when the ring material eventually falls into the atmosphere as its orbit decays over time. Although the rings are large, they contain virtually no mass as compared with the planets. Saturn's rings would certainly be visible from the planet itself, but because it lacks a solid surface, you'd have to wait for a break in the clouds while you float in your balloon gondola. The darker rings of the other planets might be similarly visible, but only if you had the

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appropriate observation instruments.

Answer originally posted December 4, 2000.

Answer posted on August 18, 2003

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ASK THE EXPERTS : ASTRONOMY

Why and how do planets rotate?

A. P. Erson

Leesburg, Fla.

George Spagna, chair of the physics department at Randolph-Macon College, explains.

Stars and planets form in the collapse of huge clouds of interstellar gas and dust. The material in these clouds is in constant motion, and the clouds themselves are in motion, orbiting in the aggregate gravity of the galaxy. As a result of this movement, the cloud will most likely have some slight rotation as seen from a point near its center. This rotation can be described as angular momentum, a conserved measure of its motion that cannot change. Conservation of angular momentum explains why an ice skater spins more rapidly as she pulls her arms in. As her arms come closer to her axis of rotation, her speed increases and her angular momentum remains the same. Similarly, her rotation slows when she extends her arms at the conclusion of the spin.

As an interstellar cloud collapses, it fragments into smaller pieces, each collapsing independently and each carrying part of the original angular momentum. The rotating clouds flatten into protostellar disks, out of which individual stars and their planets form. By a mechanism not fully understood, but believed to be associated with the strong magnetic fields associated with a young star, most of the angular momentum is transferred into the remnant accretion disk. Planets form from material in this disk, through accretion of smaller particles.

In our solar system, the giant gas planets (Jupiter, Saturn, Uranus, and Neptune) spin more rapidly on their axes than the inner planets do and possess most of the system's angular momentum. The sun itself rotates slowly, only once a month. The planets all revolve around the sun in the same direction and in virtually the same plane. In addition, they all rotate in the same general direction, with the exceptions of Venus and Uranus. These differences are believed to stem from collisions that occurred late in the planets' formation. (A similar collision is believed to have led to the formation of our moon.)

Answer posted on April 14, 2003

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How do planets acquire rings?

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Why and how do planets rotate?

How long do stars usually live?

What exactly is the North Star?

Why do stars twinkle?

If there is no gravity in space, why do "shooting stars" fall?

Why is the Oort cloud not a disc?

What is a blue moon?

Why are planets round?

Can you explain how jet propulsion engines work?

How is a star born?

Images of astronomical nebulae look startlingly like clouds on the sky on the earth, even though they are vastly different in size and composition. Why is this? Are the dynamic processes that shape these cosmic structures the same as those at work in our atmosphere?

According to the big bang, space itself is expanding. I don't understand: If space is expanding, into what is it expanding?

How do astronomers measure the distances to galaxies that are millions or even billions of light-years away? I understand that trigonometric parallax can be used to measure distances out to only a couple of hundred light-years away. How do we get from there to the edge of the universe?

How do we know that distant galaxies are composed of matter rather than anti-matter? If equal quantities of each were produced in the big bang, might not some parts of the universe contain primarily matter and other parts primarily anti-matter?

Is the violent behavior of quasars caused by black holes in galaxies? If so, does the discovery of black holes in the centers of many normal galaxies mean that all galaxies were once

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quasars?

Is it just a coincidence that the moon's period of rotation and revolution are identical, so that we always see the same face? If not, how did this situation come to be?

Astronomers have now discovered about 10 planets orbiting other stars. When and how will these planets receive names? Who gets to name them?

How do scientists determine the ages of stars? Is the technique really accurate enough to use it to verify the age of the universe?

Why are scientists so sure that the Martian meteorite that has been in the news recently really came from Mars? Couldn't it have been dislodged from Earth by an asteroid impact and then returned millions of years later? Couldn't the early Earth (or some distant asteroid) once have been chemically similar to Mars?

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Is it just a coincidence that the moon's period of rotation and revolution are identical, so that we always see the same face? If not, how did this situation come to be?

Dan Snead

Beckley, West Virginia

Alan P. Boss of the Carnegie Institution of Washington provides an answer to this question:

"The moon keeps the same face pointing towards the Earth because its rate of spin is tidally locked so that it is synchronized with its rate of revolution (the time needed to complete one orbit). In other words, the moon rotates exactly once every time it circles the Earth.

"The same forces that create tides in the Earth's oceans (from the gravitational pull of the moon and, to a lesser extent, the sun) also act on the solid body of the moon. The Earth's gravitational force on the moon distorts the moon into a slightly prolate, or football, shape; in addition the moon's intrinsic form is somewhat egg-shaped. If the tip of the football/egg does not point toward the Earth, then gravitational forces exert a torque that makes the tip point back toward the Earth (in reality, the moon oscillates a small amount around perfect alignment, a motion called the lunar libration)."

It is very unlikely that the moon started out synchronized; that would indeed be a surprising "coincidence." As Boss explains, "The moon's synchronous spin state is thought to have arisen billions of years ago, when the moon was much closer to the Earth, and so tidal forces were much stronger than at present. The Earth's gravity maintained this spin state even as other gravitational interactions caused the moon to move outward to its present orbital radius.

Answer posted on October 21, 1999

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September 19, 2003

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An article in the May 1996 issue of Scientific American ("The Kuiper Belt," by Jane X. Luu and David C. Jewitt) questioned whether Pluto "deserves the status of a full-fledged planet." What defines a true planet, and why might Pluto not qualify?

Pluto in 1930, astronomers have recognized it as an oddball, very unlike the other outer planets. The quote from Luu and Jewitt refers to the recent discovery of a population of giant, comet-like objects orbiting beyond Neptune, a zone called the Kuiper belt. Pluto lies in the vicinity of this belt, leading some astronomers to consider it the largest member of the population of small bodies at the fringe of the solar system. But does that mean it is not really a planet? It is a subjective question, one that has produced some passionate disagreements within the astronomical community.

Leslie Young, a research associate at the Boston University Center for Space Physics, offers her view:

"Should Pluto keep its planet status if it is 'merely' the largest Kuiper belt object? In this case, size does matter. Pluto is large enough to be spherical from self-gravity and probably to have an inner, dense core. It has a thin atmosphere and probably has weather and complex seasons. Although Pluto may be dynamically similar to its smaller cousins in the outer solar system, it is geologically and meteorologically very distinct. More >>

More Questions

I've read references in both science and science-fiction articles to "asteroid mining." Is this a feasible thing to do? If so, how might it be accomplished, and what kind of valuable materials could we extract?

I have heard people call Jupiter a "failed star" that just did not get big enough to shine. Does that make our sun a kind of double star? And why didn't Jupiter become a real star?

Why do the moon and the sun look so much larger near the horizon than they do high up in the sky? I have heard this called the "moon illusion" or the "Problem of Luna Mendex." Is it an illusion of the eye?

Some space probes, such as Galileo, were deliberately aimed close to planets in order to increase their velocity through a gravitational "slingshot" effect. How does this effect work? Why isn't the increased velocity achieved while approaching the planet exactly canceled as the probe leaves the planet?

What is an optical interferometer, such as the one being developed at Palomar Mountain? Specifically, how do such devices work, and what kind of new insights can they offer about astronomical bodies and phenomena?

What would be the environmental effects if the earth collided with a large comet? For instance, what would the climate be like afterward, and what forms of life would be most likely to survive?

Astronomers have reported an apparent shortage of neutrinos coming from the sun. Does that mean that nuclear fusion is shutting down inside the sun? Are we then headed for an ice age?

What process creates and maintains the beautiful spiral arms around spiral galaxies? I've been told that density waves are responsible--so where do the density waves come from?

I read that the sun's surface temperature is about 6,000 degrees Celsius but that the corona--the sun's atmosphere--is much hotter, millions of degrees. How does all that energy get into the corona without heating up the surface?

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How did scientists determine our location within the Milky Way galaxy--in other words, how do we know that our solar system is in the arm of a spiral galaxy, far from the galaxy's center?

What causes a meteor shower?

Why is the night sky dark?

If comets melt, why do they seem to last for long periods of time?

How fast is the earth moving?

If light cannot escape the gravitational pull of black holes, how is it that scientists have detected plumes of radiation coming from them?

My wife and I recently found a strange looking rock. How can we tell if it's a meteorite?

Could silicon be the basis for alien life forms, just as carbon is on Earth?

Does the fact that the universe is continually expanding mean that it lacks a physical edge?

How do we determine the life cycles of stars and tag some as "young" and some as "old?"

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ASK THE EXPERTS : ASTRONOMY

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In science fiction movies, the "asteroid belt" is always pictured as a very crowded place. How dense is it really: impossible to navigate, risky or just interesting?

David Morrison of the NASA Ames Research Center adds some additional information about collisions to last week's responses from Michael Briley and Tom Gehrels:

There are more than 100,000 asteroids larger than 1 kilometer in diameter, but these objects are distributed within the huge volume of the asteroid belt. Their average spacing is several million kilometers. Collisions are thus extremely rare; an average 1-kilometer asteroid suffers one collision every few billion years, or maybe one or two collisions over the lifetime of the solar system.

Spacecraft pass through the asteroid belt with virtually no chance of a collision, and in fact considerable effort is required for a close flyby of even one asteroid, such as the Galileo spacecraft flyby of Ida in 1993. The spacing is also so large that seen from one asteroid, even the nearest 1-kilometer asteroid would likely be too faint to be visible without a telescope.
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More Questions

Is it possible that a meteorite could strike a commercial airliner and cause it to explode? Could this possibly have caused the crash of TWA Flight 800?

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